REPORT RESUMES

ED 010 635 08

THE RELATIVE EFFECTIVENESS OF THE TRADITIONAL AND TWO MODIFIED METHODS OF ORGANIZING INFORMATION SHEETS.

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REPORT NUMBER BR-5-8458 PUB DATE SEP 66
GRANT OEG-5-8458
EDRS PRICE MF-$0.27 HC-$5.60 140P.

DESCRIPTORS- *DATA SHEETS, *VOCATIONAL EDUCATION, *INSTRUCTIONAL MATERIALS, LEARNING PROCESSES, VERBAL LEARNING, ABILITY, *RETENTION, *TRANSFER OF TRAINING, INSTRUCTIONAL DESIGN, MINNEAPOLIS, MINNESOTA

THE EFFECTIVENESS OF A TYPICAL METHOD OF ORGANIZING TECHNICAL INFORMATION SHEETS USED BY VOCATIONAL EDUCATORS TO PROVIDE UP-TO-DATE INSTRUCTION TO STUDENTS WAS COMPARED TO THAT OF TWO NEWLY DEVELOPED ORGANIZATIONS BASED ON "THE SUBSUMPTION THEORY OF MEANINGFUL VERBAL LEARNING AND RETENTION" (AUSUBEL, 1962). AN OPERATIONAL DEFINITION STATED AN ORGANIZER SHOULD (1) RELATE THE MATERIAL TO BE LEARNED TO THE PUPILS' PREVIOUS EXPERIENCE AND (2) ORGANIZE THE MATERIAL AT A HIGH LEVEL OF GENERALITY. USING THIS DEFINITION, TWO NEW ORGANIZERS WERE DEVELOPED--(1) A SUMMARY ORGANIZER AND (2) A QUESTION ORGANIZER. THE TREATMENTS WERE THREE INFORMATION SHEETS THAT WERE IDENTICAL IN ALL RESPECTS EXCEPT THAT THE TWO EXPERIMENTAL TREATMENTS EACH CONTAINED ONE OF THE NEW ORGANIZERS PLACED BETWEEN AN INTRODUCTORY MOTIVATIONAL PARAGRAPH AND THE BODY OF TECHNICAL INFORMATION, WHILE THE TRADITIONAL TREATMENT DID NOT. THE TREATMENTS WERE REPLICATED ON MODERATELY DIFFICULT MATERIALS AND ON DIFFICULT MATERIALS. TREATMENTS WERE ADMINISTERED TO POST-HIGH SCHOOL, DAY-TRADE STUDENTS ALONG WITH AN INITIAL LEARNING TEST. RETENTION AND TRANSFER TESTS WERE ADMINISTERED 6 WEEKS LATER. FINDINGS REVEALED NO SIGNIFICANT DIFFERENCES AMONG THE TREATMENTS IN TERMS OF THE AMOUNT OF INITIAL LEARNING, RETENTION, OR TRANSFER. NO SIGNIFICANT INTERACTIONS WERE FOUND BETWEEN TREATMENT AND ABILITY OR BETWEEN ABILITY AND DIFFICULTY. POSSIBLE REASONS FOR THE LACK OF DIFFERENCES FOUND WERE OUTLINED. (JH)

ED010635

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The Relative Effectiveness of the Traditional and Two Modified Methods of Organizing Information Sheets

David J. Pucel

Final Report of Project No. 5-8458
Division of Adult and Vocational Research
United States Office of Education

Department of Industrial Education
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Office of Education
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THE RELATIVE EFFECTIVENESS OF THE TRADITIONAL AND TWO MODIFIED METHODS OF ORGANIZING INFORMATION SHEETS

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Vocational and Adult Research Grant
Number 5-8458, Vocational Education Act
of 1963, Section 4(c)

The Project Reported Herein was
Supported by a Grant from the
U.S. Department of Health, Education, and Welfare
Office of Education

September 1966

ACKNOWLEDGEMENTS

As with any study, many persons contributed their assistance to the investigator. Although it is not feasible to enumerate all of the persons who assisted the investigator in this study, the writer wishes to express special gratitude to his wife, Virginia, Dr. Jerome Moss, Jr., and Dean Rupert N. Evans, without whose aid and patient understanding this study would not have been completed.

David J. Pucel
Principal Investigator

June, 1966

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS i

LIST OF TABLES AND FIGURES iv

CHAPTER

I. INTRODUCTION 1

- Statement of the Problem. 1
- Background of the Problem 2
- Objectives of the Study 18

II. PROCEDURES 20

- General Design. 20
- Instrumentation 21
  - Information Sheets 21
  - Criterion Tests. 23
  - Validation of Instruments. 24
  - Organizers 26
- Treatments. 31
- Pilot Study 31
- Population and Samples. 34
- Data Collection 37
- Analysis of the Data. 43

III. FINDINGS AND TESTS OF HYPOTHESES 44

IV. SUMMARY, CONCLUSIONS, DISCUSSION AND IMPLICATIONS. 52

Page

Summary 52

Conclusions 54

Discussion and Implications 55

SELECTED BIBLIOGRAPHY 60

APPENDIX A Blueprints of Concepts Contained in Each Information Sheet and the Items Testing Each Concept. 63

APPENDIX B The Information Sheets. 71

APPENDIX C Retention and Transfer Tests. . . . 106

APPENDIX D Composition of the Purposive Sample of Educational Psychologists and Industrial Educators, and the Panel 130

LIST OF TABLES AND FIGURES

TABLE

Page

1. TREATMENT DEFINITIONS 7
2. MEAN ABILITY OF THE POPULATION, HIGH ABILITY SAMPLE AND LOW ABILITY SAMPLE AS MEASURED BY THE AGCT 36
3. MEANS AND STANDARD DEVIATIONS OF AGE AND ABILITY OF HIGH ABILITY SUB-SAMPLES . 40
4. MEANS AND STANDARD DEVIATIONS OF AGE AND ABILITY OF LOW ABILITY SUB-SAMPLES . . . 40
5. MEANS AND STANDARD DEVIATIONS OF AGE AND ABILITY OF OVERALL SAMPLES. 40
6. CURRICULA COMPOSITION OF HIGH ABILITY SUB-SAMPLES 41
7. CURRICULA COMPOSITION OF LOW ABILITY SUB-SAMPLES 42
8. SUMMARY OF THE ANALYSIS OF INITIAL LEARNING SCORES 45
9. SUMMARY OF THE ANALYSIS OF RETENTION SCORES 46
10. SUMMARY OF THE ANALYSIS OF TRANSFER SCORES 47

FIGURE

1. METALWORKING ORGANIZER ORGANIZATION . . . 28
2. COMMUNICATIONS ORGANIZER ORGANIZATION . . 29

CHAPTER I

INTRODUCTION

Statement of the Problem

Technology is changing so rapidly that many books used in vocational classes are out of date before they are printed. Because of this, information sheets, which are teacher-made materials presented to students in an effort to provide current information, are becoming increasingly important in the teaching of vocational and technical classes. Information sheets also serve as a relatively inexpensive means of providing instruction to students at the time they have need for it, thereby allowing for certain kinds of individual differences.

As greater use is made of information sheets it becomes increasingly important to determine whether their present format leads to efficient learning. Specifically, is there another way of organizing information sheets which will serve to increase students' initial learning, retention, and/or their ability to apply the obtained knowledge to new and novel situations?

Although individual information sheets have long been used by vocational educators, the effectiveness of their organization has seldom been questioned. Since Selvidge wrote his book on individual instruction sheets in 1926 (31), it has served, relatively unchallenged, as a guide for the development of all types of instructional sheets used in vocational education. Learning theory, however, has been modified since that date. Modern educational psychologists have proposed ideas which are relevant to the construction of information sheets. It appears appropriate, therefore, to no longer take the traditional organization of the sheets for granted, but to question its relative efficacy. A more effective method for organizing information sheets could result in substantial savings in terms of training time and costs.

It was, therefore, the purpose of this study to compare the effectiveness of the typical manner of organizing information sheets with organizations based upon the "Subsumption Theory of Meaningful Verbal Learning and Retention" proposed by Ausubel (4).

Background of the Problem

As referred to earlier, educational psychologists have progressed in their understanding of meaningful verbal learning. Many authors (26, 28, 29, 33) are currently reflecting the marked trend away from traditional learning theories toward greater concern with experimentation in meaningful learning. Underwood (33, pp. 133-152) indicated that reviews of research for the period from 1950 to 1961 indicated some 1,000 reported studies dealing with human learning.

Although considerable research has been done in the area of human learning in recent years, many questions remain unanswered. Ausubel (5, p. 3) has listed three factors which he believes have contributed to this lack of knowledge: (1) most of the studies in the field of learning have been conducted by non-professional research workers in education, including teachers; (2) the more rigorous research in learning theory has been conducted by psychologists who were not connected with education; and (3) educational psychologists of the past generation have been preoccupied with measurement and evaluation, personality development, and non-cognitive approaches to learning and perception.

The traditional base for constructing information sheets is generally considered to be Herbartian theory. It has been found, however, through a review of Herbart's original work (25) and an early interpretation of Herbart (1), that the typical information sheet does not represent a pure application of Herbartian theory; it actually is a modification of the theory which has evolved over the years.

Herbart's original theoretical model can be summed up as follows (25, p. cvii):

STAGE I. Apperception (to obtain clear distinct percepts)	Step I. Clearness	A. Analysis (preparation) B. Synthesis (presentation)
STAGE II. Abstraction (to deduce accurate general notions)	Step II. Association Step III. System Step IV. Method (application, function)	

In Stage I, as a new concept is encountered by an individual it is apperceived or related to whatever previous knowledge the individual has which he perceives as being related to the new concept. In Step I, the position of the new concept is clarified. The concept is held in the mind while the mind analyzes its present content to prepare itself to acquire the new concept. The concept is then presented to those relevant existing concepts in the mind and is synthesized with them. At this point the abstraction stage (Stage II) is entered to further clarify the relationships which exist between the new concept and previously held related concepts. In Step II, associations between the new and existing related concepts are explored in order to arrive at Step III, a system for relating them. Finally, in Step IV, methods of applying this newly synthesized knowledge are tested to determine if the associations and system are correct. A relatively pure application of Herbart's theory to modern education has been summarized by his followers in the following five steps (24):

a. Preparation.
In this step related subject matter which has been learned previously is recalled. This involves Herbart's main psychological principle --the law of apperception. He held that the mind is simply one's previous experiences, and that new experiences must be related to past experiences in order to become part of one's self. When new experiences are so related, they can be consciously perceived, or apperceived. Herbart is making this point when he speaks of "apperceptive mass." Hence, the first step in teaching new material is to relate the material to something previously known.

b. Presentation.
Here the new material is presented for observation.

c. Association.
The new material is compared with the old, and likenesses and differences are noted.

d. Generalization. (Classification)
The relationships between the new and old material are given statement in definite form.

e. Application.
Practical application must be made in order to consummate the process.

Vocational educators have further modified this theory and its definitions as can be seen in the following statement by Prosser and Quigley.

> "Where instruction is called for, the vocational school has very generally used the standard Herbartian lesson, usually using only the first four steps in teaching, i.e., preparation, presentation, application and testing." (30)

Although many textbooks dealing with methods and principles of vocational education do not specifically define what each stage includes, those that do (16, 27, 31) generally define them as follows when considering an information sheet.

a. Preparation.
Prepare the student to accept the new material by motivating him to learn.

b. Presentation.
Present the new material to the learner.

c. Application and Testing.
Provide a series of questions at the end of the information which has been presented.

The obvious points of difference between Herbart's original theory and the typical interpretation which vocational educators have made as applied to the organization of information sheets are: (a) no mention is made by Herbart about student motivation, although the typical method used by vocational educators does attempt to provide motivating materials; (b) Herbart emphasizes the development of relationships between what the learner has previously experienced and the present lesson, while the typical method used by vocational educators does not.

This study assumed that it is desirable to provide motivational materials as part of the format of information sheets. Ausubel concurs by referring to such material as "an incentive which facilitates learning by means of energizing learning activity on a motivational basis" (9). The typical method of organizing an information sheet is presented in Table I, page 7,which represents the control treatment (treatment 1) in the study.

TABLE 1

TREATMENT DEFINITIONS

Treatment 1 (Typical or Control Treatment)	Treatment 2 (Summary organizer) Directive	Treatment 3 (Question organizer) Non-Directive
a. Preparation. Present a paragraph designed to provide the basis for student motivation.	a. Preparation. Present the same paragraph as that presented in the typical information sheet to provide the basis for student motivation.	a. Preparation. Present the same paragraph as that presented in the typical information sheet to provide the basis for student motivation.
b. Presentation. Present the actual information.	b. Organization. Introduce a summary (directive) organizer (Ausubel variation).	b. Organization. Introduce a question (discovery) organizer (Ausubel variation).
c. Application and Testing. Present questions pertaining to the material covered.	c. Preparation. Present the same actual information in the same form as that presented in the typical information sheet.	c. Preparation. Present the same actual information in the same form as that presented in the typical information sheet.
	d. Application and Testing. Present the same questions pertaining to the material covered as those presented in the typical information sheet.	d. Application and Testing. Present the same questions pertaining to the material covered as those presented in the typical information sheet.

The study was also concerned with adding to the typical format. Ausubel (4) agrees with Herbart that as a new idea is encountered in a learning situation it searches the cognitive structure for friends or other ideas with which it may associate, but he adds a critical factor. He points out that learning in a new situation will be more meaningful if we introduce an organizing concept, because those which are generally available in the cognitive structure are not optimal. Ausubel contends that the presentation of meaningful verbal material should be preceded by the introduction of an "advanced organizer" which serves as a focus and an anchor to which newly encountered verbal materials and concepts can fix themselves in the cognitive structure.

Ausubel's model of cognitive organization for learning and retention of meaningful materials assumes the existence of a hierarchically organized cognitive structure. Within this structure less inclusive subconcepts are subsumed under more highly inclusive concepts. The major organizational principle, in other words, is that of progressive differentiation of concepts in a given sphere of knowledge from regions of greater to lesser inclusiveness, each linked to the next higher step in the hierarchy through a process of subsumption. Therefore, as new material enters the cognitive structure, it interacts with and is subsumed under a relevant and more inclusive conceptual system. The very fact that it is subsumable or relatable to existing elements in the structure indicates its meaningfulness to the individual and makes possible the perception of insightful relationships. The initial effects of subsumption are, therefore, the facilitation of both learning and retention.

Because it is more economical for an individual to retain single inclusive concepts rather than to remember a large number of specific items, the second or obliterative stage of subsumption begins. The specific items become less and less discernable from the concept under which they are subsumed until they are no longer available and are said to be forgotten.

The introduction of a relevant organizer preceding the discussion of new meaningful verbal materials provides an optimal anchorage or focal point to which lesser inclusive sub-concepts can be subsumed. The fact that optimal anchorage is available increases the meaning of the newly acquired material which consequently slows down the obliterative effects of subsumption and tends to retard forgetting.

In an attempt to clarify his theory and place it in perspective to other learning theories, Ausubel has been a prolific writer (7, 8, 10, 11, 12, 20, pp. 221-262). Probably the best summary of what Ausubel considers to be the most relevant variables in studying meaningful verbal learning is found in Education and the Structure of Knowledge, which is the summary of the fifth annual Phi Delta Kappa symposium on educational research (20, pp. 221-262).

Because Ausubel's theory is vague in describing what actually constitutes an advanced organizer, and since the application of the organizer to the problem at hand was not limited to the restriction of his theory, two types of organizers were tested in this study as the two experimental treatments.

The organizers are defined as directive and non-directive. One of the experimental treatments added a directive or summary organizer to the typical method of presenting information sheets and the other added a discovery or question organizer. Based upon a review of Ausubel's definition of an organizer and its function by a purposive sample of educational psychologists and industrial educators (Appendix D-1), both organizers were designed to (a) relate the material to be learned to what the student had already experienced, and thereby show him where the new materials fit into his previous experience, and (b) supply an internal organizational structure at a high level of generality for the material the student was about to read. These two criteria were later used by a panel

(Appendix D-2), in a manner specified in the section on developing the organizers (Chapter II, p. 21), to verify the appropriateness of both experimental organizers.

The two experimental treatments are summarized as Treatments 2 and 3 in Table I, page 7.

Ausubel's usual approach to constructing the organizer is mainly in agreement with what this study considers to be the summary or directive organizer. He envisions the organizer as an early portion of the new meaningful verbal learning material which will perform the functions previously outlined in a directive manner (4, 6). This method assumes, however, that the group of students to which the new material is to be presented have a common background. It is because of the possible invalidity of this assumption that the question organizer has been introduced in this study. Since a major function of the organizer is to provide the student with a means of incorporating the newly encountered material into his existing cognitive structure, and since an instructor can never be sure of the student's past experience, the purposive sample of educational psychologists and industrial educators felt that a question organizer might allow the student greater flexibility in assimilating the new material regardless of the specific nature of the structure.

Ausubel also states that unless the learner finds the material "difficult," he has no need to search his cognitive structure for relevant anchorage; an organizing concept would, therefore, be unnecessary (2). Since all verbal materials presented in the form of information sheets may not be "difficult," the addition of an advanced organizer to all sheets may impose an unnecessary task upon the teacher. Thus, the organization variables were replicated with material estimated to be "difficult" and "moderctely difficult" according to the procedures outlined in the section dealing with the development of the information sheets (Chapter II, p. 21).

Ausubel has conducted several studies in an effort to substantiate his theory, two of which are especially pertinent (2, 12). Both studies were conducted with undergraduate students enrolled in senior educational psychology courses at the University of Illinois, utilizing 2500-word learning tasks presented for 35 minutes. Both experiments were evaluated on the basis of specially constructed multiple choice tests with 36 and 45 items respectively, having split-half reliabilities of .79. In the first of these two studies (2), Ausubel tested the effect of an organizer, which later became known as an expository organizer. He defined this organizer as an introductory passage, containing background material for the learning passage, which was presented at a much higher level of abstraction, generality and inclusiveness than the learning passage itself. The control introductory passage consisted of historically relevant background material. After four days, the subjects were tested for retention of the material presented in the learning task dealing with the metallurgical properties of carbon steel. It was found that the retention of the group receiving the organizer was significantly better than the group which received the control introduction.

Ausubel later attempted to test the relative effectiveness of a comparative organizer and an expository organizer (12). In this case, the learning passage dealt with Buddhism. The comparative organizer made direct references to differences between the material to be dealt with in the learning task (Buddhism) and the material from which it was to be discriminated (Christianity). The expository organizer provided a framework in which the Buddhism material could be organized without reference to Christianity. It was found that over a short period of time (3 days) the comparative organizer led to better retention than did the expository organizer, but over a longer period of time (10 days) there was no significant difference between the two. Both groups receiving the organizers did better than the control group, which did not receive any. The two experimental organizers in the proposed study are designed to incorporate the best aspects of both the comparative and expository organizers.

In most of Ausubel's studies, which are all quite similar to those which have been discussed, it has been found that the facilitating effect of organizers is more beneficial for subjects who have relatively poor verbal ability. Ausubel has hypothesized that this relationship occurs because persons with low verbal ability tend to structure verbal material less efficiently on their own. With this in mind, the sample of the present study was divided into sub-samples on the basis of verbal ability.

Two doctoral dissertations in the field of industrial education are also directly related to the present study (19, 32). Dawson (19) sought "to provide additional research evidence concerning the evaluation of the subsumption theory of learning at the junior high level." He did this by studying the effect of a 600 word organizer presented 24 hours before a 2000 word learning passage on the history, characteristics and uses of plastics and synthetics. The population consisted of 146 eighth grade students of high socio-economic background enrolled at the Cooper Intermediate School in the Washington, D. C. metropolitan area during the 1963-64 school year. The students were stratified into high and low mental maturity groups on the basis of scores on The California Test of Mental Maturity. Samples were randomly assigned and the treatments administered. The experimental group received the 600 word organizer 24 hours before reading the learning passage. The control group received only the learning passage. Criterion scores were obtained immediately following the reading of the learning passage, and three and six weeks following the reading of the learning passage. The same 52 item, 4-choice, multiple choice test (.66 split-half reliability) was used in each instance. It was found that the experimental method was significantly more effective than the control method, as measured by the initial learning and three weeks retention test, for the low ability students, but not for the high ability students. There was no significant difference between the experimental and control groups as measured by the six weeks retention test. Dawson concluded that the organizer seemed to be most effective with low mental maturity students in terms of short term retention.

Tomlinson (32) dealt with four variations of written instructional materials. The primary concern of his study was to test the relative effectiveness of four selected methods of presenting technical information. The learning task, consisting of a 3314 word passage on carbon steel was broken down into eight sequential and cumulative units containing ten sketches. The sum of the eight units and ten sketches formed a logical discussion of the metallurgical properties of carbon steel. The eight units were organized in the same sequence in all experimental treatments. The independent variables investigated in the study were: 1) high school class (junior and senior), 2) ability level (high, average and low) and 3) treatment methods. The dependent variables were: 1) initial learning as measured by a true-false and a multiple-choice test immediately following treatment presentations, and 2) retention and transfer as measured by a true-false, a multiple-choice, a free response, and a procedure test at one week and again at five weeks. The body of the eight units comprising the learning passage was identical in wording and sketches for each of the four methods. A statement (generalization) and a question (properly answered by the generalization) were composed for each of the eight units. Each statement or question was used as either a summary (in the inductive method) or an introduction (in the deductive method) for the appropriate unit. The four methods were as follows: (1) the inductive method (direct presentation and generalization after each unit), (2) the inductive-discovery method (direct presentation and question after each unit), (3) the deductive method (generalization before each unit and presentation), and (4) the inductive-discovery-confirmation method (direct presentation, question after each unit and immediate confirmation of the response to the question).

The expository method of stating generalizations, either before each of the eight units (deductive) or at the end of each of the eight units (inductive), led to superior retention and transfer five weeks after the presentation of the learning task as compared with the two discovery (question) approaches. The inductive method was superior to all other methods on the basis of the initial learning test. There was, however, an indication that the methods using discovery may be relatively more effective for low ability students than for upper ability students.

Cornwell's dissertation in the field of industrial education (18) is somewhat related to the present study in that it indicates that lower ability students tend to profit more from problem-centered instruction than do higher ability students. A set of written instruction sheets emphasizing problem situations was written covering the basic content of a college printing course and compared with the effectiveness of the conventional directed study methods. The study concluded that there was enough difference between the two approaches to teaching the same content to produce differential achievement. It also indicated that lower ability students profited more from the problem-centered instruction than did the higher ability students.

Thus, the present study was an expansion of previous research utilizing the organizing concept in the following ways: (a) it developed an operational definition of an organizer which can be used by the classroom teacher; (b) it tested the relative effectiveness of two different approaches to the utilization of this definition, and (c) it provided an integrated test of previous knowledge concerning the interaction between difficulty level of the material presented, student ability, and an organizing concept which incorporates both Ausubel's comparative and expository approaches. Before this study, all of these factors had not been investigated at one time in an attempt to determine their interrelationships.

Objectives of the Study

Answers to the following fifteen questions were sought:

1-3 Are there differences in amount of (a) initial learning, (b) retention, and/or (c) transfer among the three treatment populations using moderately difficult material?

4-6 Are there differences in amount of (a) initial learning, (b) retention, and/or (c) transfer among the three treatment populations using difficult material?

7-9 Are there interactions between student ability and treatment in the analyses of (a) initial learning, (b) retention, and/or (c) transfer using moderately difficult material?

10-12 Are there interactions between student ability and treatment in the analyses of (a) initial learning, (b) retention, and/or (c) transfer using difficult material?

13-15 Are there interactions between student ability and difficulty of material in the analyses of (a) initial learning, (b) retention, and/or (c) transfer?

CHAPTER II

PROCEDURES

General Design

A 2 x 3 x 2 three-way nested analysis of variance design was utilized because of its unique capabilities to provide answers to the questions stated in the objectives. With this design it was possible to test each of the questions dealing with (a) the independent variables of student ability levels (high, low), treatments (typical, summary organizer, question organizer), and difficulty levels of material (moderately difficult, difficult), and (b) the dependent or criterion variables of initial learning, retention and transfer.

DIFFICULTY (A)

	I			II		
ABILITY (C) / TRTS (B)	1	2	3	1	2	3
1						
2						

SOURCE OF VARIATION	INFORMATION OBTAINED
A	Difference between the two averages of the three treatment effects between levels of difficulty
$B(A_I)$	Differences among the treatment effects within difficulty level I
$B(A_{II})$	Differences among the treatment effects within difficulty level II

SOURCE OF VARIATION	INFORMATION OBTAINED
C	Difference between ability levels
AC	Interaction of ability and difficulty
$CB(A_I)$	Interaction of treatment and ability within difficulty level I
$CB(A_{II})$	Interaction of treatment and ability within difficulty level II
S(ABC)	Error

The same design was used to analyze the initial learning, retention, and transfer test scores. In each analysis (initial learning, retention, and transfer) $B(A_I)$ provided answers to questions 1, 2 and 3, $B(A_{II})$ provided answers to 4, 5, and 6, $CB(A_I)$ provided answers to 7, 8 and 9, $CB(A_{II})$ provided answers to 10, 11 and 12, and AC provided answers to questions 13, 14 and 15.

Instrumentation

Information Sheets

Two information sheets dealing respectively with the metalworking and communications potential of the laser were developed. Both contained: (1) an introductory passage designed to motivate the subjects to read and study the body of technical information, (2) narrative technical information making up the body of the information sheet, and (3) six essay-type questions making up the initial learning test.

The laser was selected as the general subject of both information sheets because it is a relatively new development with which few vocational students are familiar, and due to its many uses, lends itself to the development of information sheets at various levels of difficulty. The "moderately difficult" material in the study consisted of a 1775 word discussion of metalworking applications of the laser, accompanied by six illustrations which clarified the content. The "difficult" material in the study consisted of a 2180 word discussion of the laser beam as a communication media, accompanied by two illustrations. The technical information contained in each of the information sheets was abstracted from current literature available in the University of Minnesota's Engineering Library (17, 21).

Both information sheets (moderately difficult and difficult) were written at the same level of reading difficulty, as measured by the Flesch reading difficulty formula (22) (requiring high school education) and the opinions of a panel consisting of two University of Minnesota, Department of Industrial Education staff members and two electronics instructors in the post-high school technical program at the Minneapolis Area Vocational-Technical School (Appendix D-2). The reading level of the information sheets was judged to be appropriate for the subjects in this study who were post-high school, full-time, day trade students.

Upon completing the formulation of the narrative bodies of the information sheets, the introductory motivational passages were logically formulated on the basis of the narrative materials (Appendix B).

Criterion Tests

The initial learning tests were formulated in the following manner. The entire narrative bodies of the two information sheets (metalworking and communications) were outlined in terms of the smallest logical divisions of the material which contained testable content. Henceforth, these outlines will be referred to as "blueprints" (Appendix A).

On the basis of discussions with members of the University of Minnesota's Industrial Education staff, and review of several commercially produced technical information sheets, it was determined that a group of six open-ended essay type test items was representative of the number and type of test items "typically" following the body of an information sheet. Therefore, the blueprinted content in each of the information sheets was divided into six logical divisions in such a way that the content in each division was somewhat homogeneous. Two open-ended essay type test items and scoring criteria for each item were then constructed for each division. The "best" test item for each division was then selected by the panel to become part of the initial learning tests (Appendix B).

The retention test and the transfer test were constructed for each of the two information sheets using the respective blueprints as test item construction guides. One-third more items were constructed for each of the retention and transfer tests than were expected to appear in the final instruments in order that those items determined to be "poor" by the pilot study and subsequent item analyses could be eliminated.

The retention test and transfer test items (Appendix C) were constructed according to Bloom's definitions of tests of "knowledge" and "application" respectively, as found in his Taxonomy of Educational Objectives (Cognitive Domain) (15) (Refer to blueprints, Appendix A).

Validation of Instruments

Upon completing the initial development of the information sheets, blueprints, initial learning tests, retention tests and transfer tests, all were reviewed by the panel. Individual panel members were asked to judge (1) the "typicalness" of the organization of the information sheets against the criteria established for the control treatment (treatment 1) in Chapter I, (2) the "appropriateness" of the reading level of the information sheets for post-high school, full-time, day trade, vocational-technical students, (3) the adequacy with which the content of the information sheets was broken down into its smallest testable units as indicated by the blueprints, (4) the adequacy with which the content of the information sheets was sampled in the initial learning tests, the content validity of the items making up the initial learning tests, and the appropriateness of the scoring criteria for each item, (5) the adequacy with which the content of the information sheets was sampled in the retention tests and the transfer tests, whether or not the items satisfied Bloom's definitions of items testing "knowledge" or "application," and the content validity of each item, and (6) which of the two information sheets was "most difficult" as judged against the criteria of the number of concepts presented and the complexity of the relationships between the concepts.

As members of the panel completed their review, the experimenter met with them separately to review the suggestions they had concerning the materials they had reviewed. After reviewing all of the suggestions and corrections, those which seemed to represent a consensus of opinion were incorporated in a revision of the materials. The panel members unanimously agreed that the communications information sheet was more difficult than the metalworking information sheet. This judgment was supported by the relative number of concepts contained in each as indicated by their respective blueprints.

Organizers

As indicated in Chapter I, Ausubel has not operationally defined an organizer. His conception of an organizer is best summarized in the following excerpt from a letter which he wrote to Kenneth Dawson (9).

> "I define an organizer as introductory material that is structured at a higher level of generality, abstraction, and inclusiveness than the learning material it introduces. An expository organizer is used to introduce totally unfamiliar material. Its function is merely to provide ideational anchorage for the learning material. A comparative organizer is used to introduce material that is relatable to previously learned material. In addition to providing anchorage for the learning material, it attempts to increase discriminability between the new ideas to be learned and previously learned ideas. It does this by explicitly delineating, at a high level of abstraction, generality, and inclusiveness, the principal similarities and differences between the two sets of ideas. Both expository and comparative organizers are formulated in terms of concepts and propositions that are familiar to the learner.
>
> The use of organizers represents an attempt to facilitate meaningful learning by deliberately manipulating cognitive structure so as to make available to the learner the most relevant and appropriate background ideas and information to be learned. In contrast to 'a goal of behavior' it is a form of cognitive facilitation of learning rather than an incentive which facilitates learning by means of energizing learning activity on a motivational basis."

Using this definition as a base, a number of informal discussions were held in a research planning seminar (including Dr. Cyril J. Hoyt and Dr. Paul E. Johnson). Based on these discussions it was determined that two kinds of organizers, non-directive and directive, could logically be developed according to Ausubel's psychological definition. Both approaches fulfill the criteria of (a) relating the material to be learned to what the student has already experienced, thereby showing him where the new materials fit into his previous experiences, and (b) supplying an internal organizational structure at a high level of generality for the material which the student is about to read.

The summary organizer approach was defined as directive and is essentially the same as Ausubel's expository organizer. The question organizer, or the non-directive approach, is felt to be another method of accomplishing the same purposes while allowing for greater degrees of individual differences.

Since the summary organizer represents a narrative explanation of the answers to the questions posed in the question organizer, the following discussion of the organization of the organizers will be in terms of the question organizer.

The organizers are sequenced from abstract to particular. (See Figures 1 and 2). They begin with very general questions aimed at preparing the student to think about the topic to be presented. Questions are asked which lead his thinking from very general past experiences to past experiences which are directly related to the topic

Figure 1

METALWORKING ORGANIZER ORGANIZATION

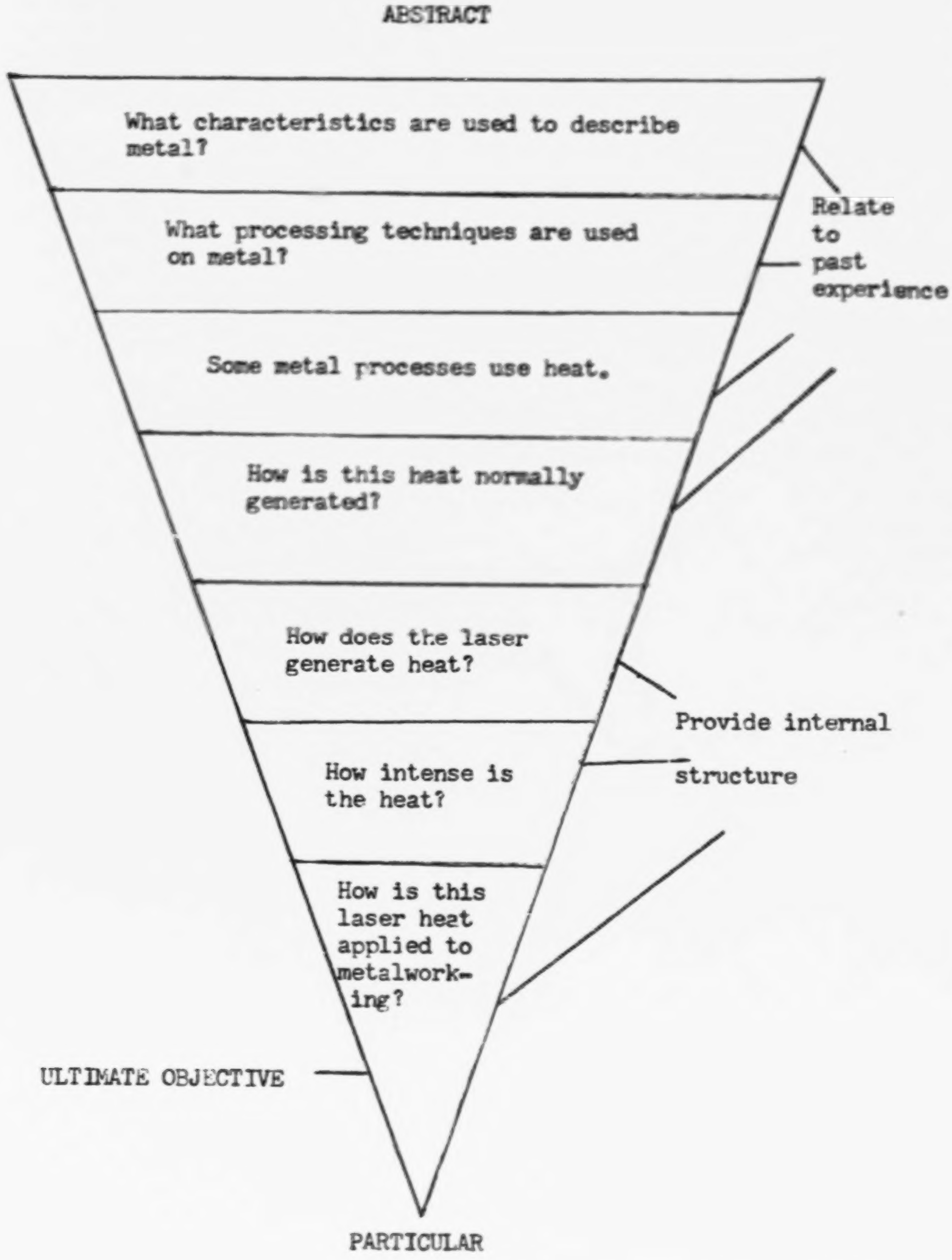
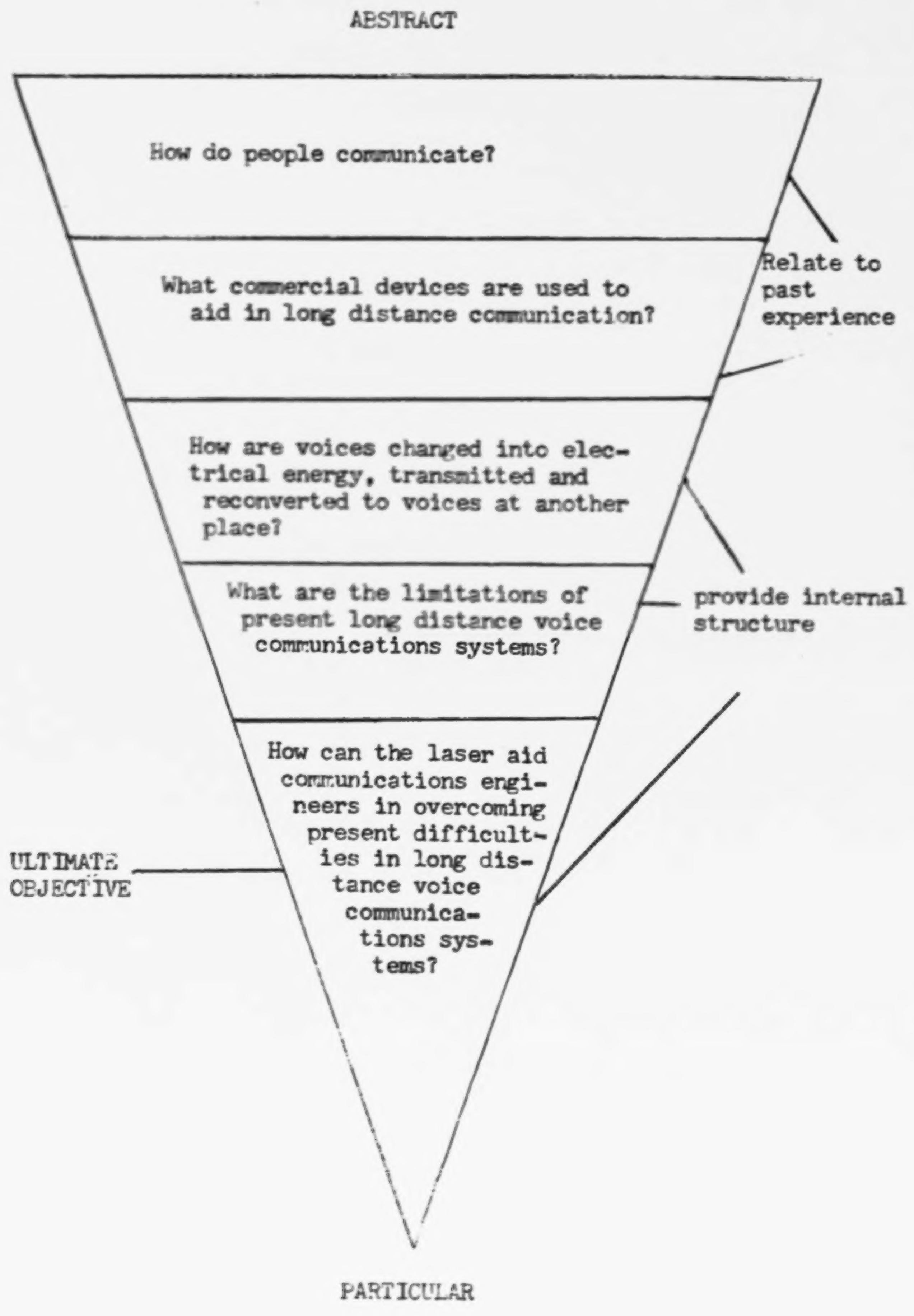

ABSTRACT
What characteristics are used to describe metal?
What processing techniques are used on metal?
Some metal processes use heat.
How is this heat normally generated?
How does the laser generate heat?
How intense is the heat?
How is this laser heat applied to metalworking?
Relate to past experience
Provide internal structure
ULTIMATE OBJECTIVE
PARTICULAR

Figure 2

COMMUNICATIONS ORGANIZER ORGANIZATION


ABSTRACT
How do people communicate?
What commercial devices are used to aid in long distance communication?
Relate to past experience
How are voices changed into electrical energy, transmitted and reconverted to voices at another place?
What are the limitations of present long distance voice communications systems?
provide internal structure
How can the laser aid communications engineers in overcoming present difficulties in long distance voice communications systems?
ULTIMATE OBJECTIVE
PARTICULAR

to be discussed. This group of questions, and the answers to them, serves the purpose of relating the expected past experiences of the students to the topic to be discussed. Once the appropriate past experience is recalled, a series of general questions covering the major concepts to be presented in the new material are posed. These questions are constructed both to identify the internal structure of the new material, and to require the students to compare the new with the old related materials. The students are not expected to be able to answer these questions prior to reading the material. They are posed to provide the learner with an overall picture of the internal structure of the information to be presented, to indicate the key concepts to be found in the information, and to indicate relationships between the new and old materials. This group of questions concludes with a question which indicates the ultimate learning objective of the material to be presented. For example, the ultimate objective of the communications information sheet is that the students know how the laser can aid communications engineers in overcoming present difficulties in long distance voice communications; the ultimate object of the metalworking information sheet is that the students know how the laser can be applied to metal processing.

As indicated previously, the summary organizer represents an attempt by the instructor to answer the questions posed in the question organizer. By providing the answers to these questions the instructor assumes that he "knows" what knowledge or previous learning the students will relate to the topic covered in the information sheet. The final organizers can be found at the beginning of each of the information sheets presented in Appendix B.

Treatments

The study investigated the relative effectiveness of three treatments--a control treatment (treatment 1), which consisted of the traditional information sheet described in Chapter I, and two experimental treatments (treatments 2 and 3). The experimental treatments were identical to the control treatment in all respects except that each experimental treatment included one form of an organizer immediately following the introductory motivational paragraph (see Table 1, page 7). Each of the three treatments was applied to both the communications (difficult) and the metalworking (moderately difficult) information sheets, making a total of six treatments.

Pilot Study

The purposes of the pilot study were to perfect the test instruments and to test the procedures involved in conducting the study. Arrangements were made with Mr. Harold

M. Ostrem, Director of Vocational and Adult Education, St. Paul, Mr. Edwin L. Stull, Assistant Principal, St. Paul Vocational-Technical Institute, and Mr. John E. Grossman, Instructor, St. Paul Vocational-Technical Institute, to conduct a pilot study with 89 students enrolled in the post-high school, full-time, day trade physics course offered at the St. Paul Vocational-Technical Institute. The physics course was selected because all persons enrolled in the full-time, post-high school, day trade programs of the Institute are required to take the course. At any given time, the four sections of the course represent a sampling of persons enrolled in all of the trade areas. The six treatments were arranged prior to beginning the pilot study so that every sixth person in a class would receive the same treatment and no two adjacent persons would receive the same information sheet or an information sheet on the same subject. Using this procedure, all treatments were equally represented and an "approximate" randomization of treatments to subjects was achieved.

On Monday, January 24, 1966 the investigator administered the treatments to 89 subjects and collected the initial learning test data. One week later, January 31, 1966, he returned and administered the retention and transfer tests to the 75 students in attendance who took part in the first session. The answers were recorded directly on

Digitek answer sheets for ease in scoring and item analysis.

The essay-type items of the initial learning tests were scored separately by two persons on the University's Industrial Education staff, according to the scoring criteria constructed during the development of the initial learning tests. It was found that the scorers were in near perfect agreement on the metalworking initial learning test. However, a consistent disagreement between the two scorers was found among the communications initial learning test scores. Upon examining the scores assigned to individual items by the two scorers, it was found that the scoring criteria for the first item were ambiguous. After consultation with the scorers, the criteria were clarified and a word was removed from the test item itself.

The two retention tests and the two transfer tests (one each for metalworking and for communications) were scored separately and item analyzed by the University of Minnesota's Student Counseling Bureau Digitek system.

Item analyses were run on each of the four tests, yielding a point biserial correlation between the score on a given item and the score on the total test, the percentage of students answering each item correctly, the discrimination power of each item using the split half method (percentage of top half answering the item correctly minus the percentage of the bottom half answering the items correctly) and the reliability of each test using Kuder-Richardson "formula 20."

The reliabilities of each of the four tests were as follows: metalworking retention (.90), metalworking transfer (.81), communications retention (.84) and the communications transfer (.49).

The items in each test were reviewed and judged "good" items if they fulfilled all of the following criteria: (1) a point biserial correlation of more than .20, (2) a positive discrimination index, and (3) more than 10 per cent but less than 90 per cent of the subjects answered the item correctly. Those items which did not fulfill all of the criteria were either revised, discarded and not replaced, or discarded and replaced. An item was revised if its fault was apparent and improvement was possible. An item was discarded if a revision did not seem possible. If discarding an item affected the test's validity by leaving a body of content unsampled, it was replaced. After carefully reviewing each item in each of the tests, 45 items were selected for each of the retention tests and 25 items were selected for each of the transfer tests (Appendix C).

Population and Samples

Arrangements were made with the following persons in the Minneapolis School System to conduct the study at the Minneapolis Area Vocational-Technical School: Dr.

Robert Rainey, Consultant in Educational Research, Mr. Raymond Nord, Director of Vocational Education, Mr. Norman Jensen, Principal, and Mr. Reuben Schafer, Technical Institute Program Coordinator. The population consisted of all the male students enrolled in the post-high school, full-time, day trade programs at the Minneapolis Area Vocational-Technical School during the second semester of the 1965-66 school year, with the exception of those enrolled in the electronics curriculum. The population of 180 students consisted of 8 architectural drafting, 11 auto mechanics, 23 aviation mechanics, 13 cabinet making, 35 electricity, 34 machine drafting, 10 machine shop, 8 patternmaking, 27 printing, and 11 data processing, retail sales and accounting students. Students enrolled in the electronics courses were not included in the population in an attempt to make the population more homogeneous with respect to their prior knowledge of the laser. The electricity students were included only after the electricity instructors read the laser information sheets and assured the investigator that the content of their curriculum did not contain any information which would directly contaminate the experiment.

Since the school administered the Army General Classification Test (AGCT) to all entering students, the scores were used in the study as a measure of general ability.

The AGCT raw scores of the population were ordered from high to low; the median was found to 100.5. Those students falling above the median were placed in the high ability group and those below the median in the low ability group. The mean AGCT raw score for the total population, the high ability group, and the low ability group, as well as the AGCT percentile norm for the 12th grade, are shown in Table 2.

TABLE 2

MEAN ABILITY OF THE POPULATION,
HIGH ABILITY SAMPLE AND LOW ABILITY SAMPLE
AS MEASURED BY THE AGCT

Group	Mean AGCT Raw Score	12th Grade Percentile
Total pop.	100.01	approx. 80%
High ability	108.82	approx. 90%
Low ability	90.58	approx. 58%

In an attempt to control the possible effects of differences between persons enrolled in the various vocational programs, both the high and low ability groups were stratified according to curricula. Six random samples of 30 students each were drawn such that each of the six samples included 15 subjects of high ability and 15 subjects of low ability. The six sub-samples of 15 high ability subjects were selected in such a way that each sub-sample included an equal representation of students from the various curriculums. The six low ability sub-samples were formulated in the same manner. The first 12 subjects randomly assigned to each of the six high and six low ability groups were considered to be the "regular" subjects and the last three assigned to each group to be the "alternates." Alternates were assigned in an effort to maintain equal numbers in each cell during the analysis of the data upon recommendation by the University of Minnesota's Numerical Analysis Center. Each of the six samples, containing one of the high and one of the low ability groups, was then randomly assigned to one of the two difficulty levels and to one of the three treatments within that difficulty level.

Data Collection

The first phase of testing, including the reading of the information sheets and completing the initial learning test, was conducted on the afternoon of March 10 and the morning of March 11. The first phase was administered to 176 of the 180 students contained in the samples, plus approximately 50 other students, who, due to lack of supervising instructors in the classroom caused by the testing, were required to attend. In order to approximate the "typical" method of using an information sheet, the students were allowed as much time as they needed to read the information sheets and to answer the initial learning questions. They were also allowed to go back into the information sheets to answer the questions. As a motivational device they were told that their scores would be posted so they could see how well they did relative to their classmates.

The initial learning tests were scored by the same two persons who scored the pilot study. Interscorer reliability, obtained by using the common Pearson product moment correlation, for the two initial learning tests were .93 for the metalworking test and .94 for the communications test. The average of the two scores assigned by the two scorers for a given individual was considered to be his initial learning score.

On the afternoons of April 18 and April 20, 1966, approximately six weeks after the first phase of testing, the retention and transfer tests were administered to 162 of the 176 students who participated in the first phase. The reliabilities of the respective tests, as calculated using Kuder-Richardson "formula 20," were found to be metalworking retention (.81), metalworking transfer (.67), communications retention (.81), and communications transfer

(.68). Due to absence from one or more of the testing phases a number of persons had to be dropped from the original samples. However, at least 12 persons in each treatment sub-sample consisting of the 12 regulars and 3 alternates completed the entire program. In cases where more than 12 persons in a given sub-sample completed the entire program, pre-assigned alternates were eliminated in order that the number of subjects in each cell would be equal (N = 12 in each cell). The final samples were each composed of 24 subjects (12 of high ability and 12 of low). One-way analyses of variance were used to determine whether the mean ability and age of the six sub-samples of high ability were significantly different and whether the mean ability and age of the six sub-samples of low ability were significantly different. The same was done for the total samples. There were no significant differences in mean age or ability among the six high ability sub-samples, among the six low ability sub-samples or among the six overall samples. Tables 3, 4 and 5 show the means and standard deviations of age and ability for the high and low ability sub-samples and the overall samples.

Due to the elimination of a number of the members of the original samples because of their absence from either phase of the testing program, and the limited number of students enrolled in some curricula, the composition of

TABLE 3

MEANS AND STANDARD DEVIATIONS OF AGE AND ABILITY OF HIGH ABILITY SUB-SAMPLES (N=12 PER CELL)

Sample		1	2	3	4	5	6	Overall	
	$\bar{x}$=	19.25	18.83	19.58	18.50	19.92	19.58	19.28	F=.64
Age*	s=	2.18	1.03	3.09	.52	2.75	2.84	2.25	
	$\bar{x}$=	108.58	110.58	110.17	108.67	109.17	108.00	109.19	F=.30
Ability**	s=	4.28	7.95	6.25	6.36	6.26	6.06	6.12	

*Age in full years **AGCT raw score

F .05 = 2.37

TABLE 4

MEANS AND STANDARD DEVIATIONS OF AGE AND ABILITY OF LOW ABILITY SUB-SAMPLES (N=12 PER CELL)

Sample		1	2	3	4	5	6	Overall	
	$\bar{x}$=	19.08	19.08	18.58	19.17	20.92	20.08	19.49	F=.92
Age*	s=	4.27	.90	1.46	.57	6.69	2.12	3.39	
	$\bar{x}$=	89.33	91.00	88.83	90.08	89.67	90.67	89.93	F=.11
Ability**	s=	7.89	6.98	9.82	11.11	7.25	7.02	8.22	

*Age in full years **AGCT raw score

F .05 = 2.37

TABLE 5

MEANS AND STANDARD DEVIATIONS OF AGE AND ABILITY OF OVERALL SAMPLES (N=24 PER CELL)

Sample		1	2	3	4	5	6	Overall	
	$\bar{x}$=	19.96	18.96	19.08	18.83	20.42	19.83	19.51	F=1.21
Age*	s=	3.39	.95	2.25	.64	5.03	2.51	2.88	
	$\bar{x}$=	98.96	100.79	99.50	99.38	99.42	99.33	99.56	F=.06
Ability**	s=	11.79	12.41	13.57	12.96	11.96	10.45	12.08	

*Age in full years **AGCT raw score

F .05 = 2.29

the final samples in terms of students enrolled in specific curriculums was not equal. Table 6 shows the composition of the six high ability sub-samples in terms of the number of persons contained in each sample enrolled in a given curriculum. Table 7 provides the same information for the six low ability sub-samples.

TABLE 6

CURRICULA COMPOSITION OF HIGH ABILITY SUB-SAMPLES

		A	AD	AM	C	CM	E	MD	MS	P	PM	
Sample	1	1	1	0	2	0	2	3	1	2	0	12
	2	1	1	1	1	1	2	3	0	1	1	12
	3	2	1	0	1	1	2	3	1	1	0	12
	4	2	2	1	0	1	1	3	0	2	0	12
	5	1	1	0	1	1	2	3	1	1	1	12
	6	2	2	0	0	0	2	3	0	2	1	12
		9	8	2	5	4	11	18	3	9	3	72

(A=Aviation; AD=Architectural Drafting; AM=Auto Mechanics; C= Communications; CM=Cabinet Making; E=Electricity; MD=Machine Drafting; MS=Machine Shop; P=Printing; PM= Patternmaking)

TABLE 7

CURRICULA COMPOSITION OF LOW ABILITY SUB-SAMPLES

		A	AD	AM	C	CM	E	MD	MS	P	PM	
Sample	1	2	0	1	0	3	1	3	0	2	0	12
	2	1	0	1	1	1	3	1	1	2	1	12
	3	2	0	0	1	1	3	2	1	2	0	12
	4	1	0	0	0	2	5	2	1	1	0	12
	5	1	0	1	1	1	4	1	2	1	0	12
	6	2	0	1	1	1	3	2	0	1	1	12
		9	0	4	4	9	19	11	5	9	2	72

(A=Aviation; AD=Architectural Drafting; AM=Auto Mechanics; C=Communications; CM=Cabinet Making; E=Electricity; MD=Machine Drafting; MS=Machine Shop; P=Printing; PM=Patternmaking)

Although the composition of the samples in terms of the number of persons enrolled in given curriculums was not equal, in most cases the deviations were not more than one. However, the composition of the six low ability samples did deviate by as much as 4 in terms of the number of persons enrolled in electricity courses. A one-way analysis of variance was used to investigate whether or not persons enrolled in the electricity courses did significantly better on the tests than those not enrolled in electricity. Since no significant difference was found in the test scores, the variation in the composition of the sample was not considered important.

Analysis of the Data

The analysis of the criterion measures was performed according to the three-way nested analysis of variance design described earlier in the General Design section of Chapter II. The analyses were performed utilizing computer program UMSTAT 51 at the University of Minnesota's Numerical Analysis Center and checked by hand calculation.

CHAPTER III

FINDINGS AND TESTS OF HYPOTHESES

The basic data obtained from the study concerning the effects of the three organizational methods on the ability of students to initially learn technical material, retain the material and transfer the material to new and novel situations for both the moderately difficult and difficult material is summarized in Tables 8, 9, and 10 respectively.

The findings and tests of hypotheses provided the following answers to the questions asked in the study.

Questions 1-3:

> Are there differences in amount of (a) initial learning, (b) retention, and/or (c) transfer among the three treatment populations using moderately difficult material?

No significant differences were detected between the three treatment populations using moderately difficult material as measured by the mean scores on the initial learning, retention or transfer tests.

Questions 4-6:

> Are there differences in amount of (a) initial learning, (b) retention, and/or (c) transfer among the three treatment populations using difficult

TABLE 8

SUMMARY OF THE ANALYSIS OF INITIAL LEARNING SCORES

Difficulty (A)

		TRTS (B)	I (Moderately Difficult) trad. 1	I (Moderately Difficult) sum. 2	I (Moderately Difficult) quest. 3	II (Difficult) trad. 1	II (Difficult) sum. 2	II (Difficult) quest. 3		Overall
Ability (C)	H	$\bar{x}$=41.67 s= 6.68	$\bar{x}$=42.17 s= 6.85	$\bar{x}$=41.83 s= 6.02	$\bar{x}$=41.00 s= 7.62	$\bar{x}$=39.33 s=10.34	$\bar{x}$=41.00 s= 7.93	$\bar{x}$=43.75 s= 6.25	$\bar{x}$=41.36 s= 8.32	$\bar{x}$=41.51 s= 7.49
	L	$\bar{x}$=36.56 s= 9.03	$\bar{x}$=34.33 s=11.14	$\bar{x}$=37.00 s= 5.17	$\bar{x}$=38.33 s= 9.96	$\bar{x}$=33.00 s=12.29	$\bar{x}$=33.25 s=13.19	$\bar{x}$=34.67 s= 7.25	$\bar{x}$=33.67 s=10.91	$\bar{x}$=35.10 s=10.05
totals		$\bar{x}$=39.11 s= 8.29	$\bar{x}$=38.25 s= 9.89	$\bar{x}$=39.42 s= 6.02	$\bar{x}$=39.67 s= 8.78	$\bar{x}$=36.17 s=11.58	$\bar{x}$=37.13 s=11.36	$\bar{x}$=39.21 s= 8.09	$\bar{x}$=37.50 s=10.39	GT $\bar{x}$=38.31 s= 9.40

N=12 in each cell

SV	df	MS	F	$.<P<.$
A	1	93.44	1.09	.25-.50
$B(A_I)$	2	13.72	.16	.75-.90
$B(A_{II})$	2	58.04	.67	.50-.75
C	1	1482.25	17.29	$P<.0005$
AC	1	61.36	.72	.25-.50
$CB(A_I)$	2	40.39	.47	.50-.75
$CB(A_{II})$	2	11.35	.13	.75-.90
S(ABC)	132	85.73		

p=probability of the difference occurring by chance

TABLE 9

SUMMARY OF THE
ANALYSIS OF RETENTION SCORES

Difficulty (A)

		TRTs (B)	I (Moderately Difficult) trad. 1	sum. 2	quest. 3	II (Difficult) trad. 1	sum. 2	quest. 3		Overall
Ability (C)	H	$\bar{x}$=30.17 s= 5.87	$\bar{x}$=29.42 s= 5.97	$\bar{x}$=28.58 s= 7.05	$\bar{x}$=32.50 s= 3.87	$\bar{x}$=32.58 s= 5.50	$\bar{x}$=30.25 s= 7.13	$\bar{x}$=29.25 s= 7.97	$\bar{x}$=30.69 s= 6.89	$\bar{x}$=30.43 s= 6.36
	L	$\bar{x}$=24.22 s= 5.50	$\bar{x}$=25.25 s= 6.32	$\bar{x}$=23.92 s= 4.54	$\bar{x}$=23.50 s= 5.82	$\bar{x}$=22.42 s= 5.37	$\bar{x}$=25.25 s= 5.50	$\bar{x}$=25.92 s= 5.22	$\bar{x}$=24.53 s= 5.43	$\bar{x}$=24.38 s= 5.43
Totals		$\bar{x}$=27.19 s= 6.40	$\bar{x}$=27.33 s= 6.39	$\bar{x}$=26.25 s= 6.27	$\bar{x}$=28.00 s= 6.67	$\bar{x}$=27.50 s= 7.43	$\bar{x}$=27.75 s= 6.73	$\bar{x}$=27.58 s= 6.80	$\bar{x}$=27.61 s= 6.90	GT $\bar{x}$=27.40 s= 6.63

N=12 in each cell

SV	df	MS	F	.<P<.
A	1	6.25	.18	.50-.75
$B(A_I)$	2	18.72	.53	.25-.50
$B(A_{II})$	2	.39	.01	.90-.95
C	1	1320.11	37.20	P<.0005
AC	1	.44	.01	.90-.95
$CB(A_I)$	2	42.39	1.19	.10-.25
$CB(A_{II})$	2	76.17	2.15	.10-.25
S(ABC)	132	35.49		

p=probability of the difference occurring by chance

Kuder-Richardson reliabilities of retention tests - Metalworking .81 Communications .81

TABLE 10

SUMMARY OF THE
ANALYSIS OF TRANSFER SCORES

Difficulty (A)

			I (Moderately Difficult)			II (Difficult)				
		TRTs (B)	trad. 1	sum. 2	quest. 3	trad. 1	sum. 2	quest. 3		Overall
Ability (C)	H	$\bar{x}$=16.36 s= 3.24	$\bar{x}$=16.00 s= 3.52	$\bar{x}$=16.42 s= 3.52	$\bar{x}$=16.67 s= 2.90	$\bar{x}$=14.83 s= 3.24	$\bar{x}$=15.67 s= 3.55	$\bar{x}$=14.00 s= 1.90	$\bar{x}$=14.83 s= 2.98	$\bar{x}$=15.60 s= 3.19
	L	$\bar{x}$=13.94 s= 3.55	$\bar{x}$=14.00 s= 3.27	$\bar{x}$=14.00 s= 3.44	$\bar{x}$=13.83 s= 4.17	$\bar{x}$=12.33 s= 3.77	$\bar{x}$=13.08 s= 3.61	$\bar{x}$=13.58 s= 2.97	$\bar{x}$=13.00 s= 3.41	$\bar{x}$=13.47 s= 3.48
totals		$\bar{x}$=15.15 s= 3.59	$\bar{x}$=15.00 s= 3.48	$\bar{x}$=15.21 s= 3.62	$\bar{x}$=15.25 s= 3.81	$\bar{x}$=13.58 s= 3.67	$\bar{x}$=14.38 s= 3.74	$\bar{x}$=13.79 s= 2.45	$\bar{x}$=13.92 s= 3.32	GT $\bar{x}$=14.53 s= 3.49

N=12 in each cell

SV	df	MS	F	.<P<.
A	1	55.01	4.85	.025-.05
$B(A_I)$	2	.43	.04	.75-.90
$B(A_{II})$	2	4.04	.36	.50-.75
C	1	162.56	14.34	P<.0005
AC	1	3.06	.27	.50-.75
$CB(A_I)$	2	1.04	.09	.75-90
$CB(A_{II})$	2	9.04	.80	.25-.50
S(ABC)	132	11.33		

p=probability of the difference occurring by chance

Kuder-Richardson
reliabilities of transfer tests - Metalworking .68 Communications .67

material?

No significant differences were detected between the three treatment populations using difficult material as measured by the mean scores on the initial learning, retention or transfer tests.

Questions 7-9:

> Are there interactions between student ability and treatment in the analyses of (a) initial learning, (b) retention, and/or (c) transfer using moderately difficult material?

No significant interactions were detected between ability and treatment in the analyses of the mean scores on the initial learning, retention or transfer tests using moderately difficult material.

Questions 10-12:

> Are there interactions between student ability and treatment in the analyses of (a) initial learning, (b) retention, and/or (c) transfer using difficult material?

No significant interactions were detected between ability and treatment in the analyses of the mean scores on the initial learning, retention or transfer tests using difficult material.

Questions 13-15:

> Are there interactions between student ability

and difficulty of material in the analyses of (a) initial learning, (b) retention, and/or (c) transfer?

No significant interactions between ability and difficulty were detected in the analyses of the mean scores on the initial learning, retention or transfer tests.

In summary, each treatment was equally effective in presenting both the moderately difficult and difficult materials and there were no significant interactions between treatment and ability or ability and difficulty.

As one would expect due to the sampling procedure used, there was a significant difference between the mean scores achieved by the high ability and low ability groups in each analysis.

There was no significant difference between the overall mean scores on the two difficulty levels of treatments obtained from the two initial learning tests nor the standard deviations of the two tests. The lack of difference can be attributed to the fact that students were allowed to go back into the information sheets to look up the answer for both the moderately difficult and difficult materials.

Likewise, no significant differences were found between the overall mean scores on the two difficulty levels of treatments obtained from the two retention tests or their standard deviations. Due to the way the tests were constructed this is understandable. Both tests contained multiple-choice items constructed to measure the ability of students to remember small units of factual information identified in the respective blueprints. They were not designed to measure understanding of the basic concepts or principles involved as were the transfer tests. Since the tests were designed to measure the ability of students to remember factual information and the difficulty level of the material in the information sheets was judged according to the number of concepts presented and the complexity of the relationships between the concepts, the fact that the retention tests did not reflect differences in the difficulty of the material is understandable.

A significant difference was found between the overall mean scores on the two difficulty levels of treatments obtained from the two transfer tests. This difference is again a reflection of the procedure used in constructing the tests. The transfer tests, in contrast to the retention tests, were designed to test the ability of students to apply the material presented in the information sheets. Therefore, in order to answer the transfer items correctly, the students were required to comprehend the concepts or principles involved in the information sheets. Since the number of concepts and the relationships between the concepts was more complex in the difficult (communications) material than the moderately difficult (metalworking) material, the tests of understanding logically reflected this difference.

CHAPTER IV

SUMMARY, CONCLUSIONS AND IMPLICATIONS

Summary

In general, this study investigated the relative effectiveness of the typical method of organizing information sheets used by vocational educators with two organizations based upon "The Subsumption Theory of Meaningful Verbal Learning and Retention" proposed by Ausubel. Possible interactions between these treatments and student ability, and between student ability and the difficulty level of material contained in the information sheets were also investigated.

To accomplish these purposes, Ausubel's definition of an organizer was operationally defined by a small purposive sample of educational psychologists ana industrial educators. Based on a review of Ausubel's writing, the members of the sample agreed that an organizer should (a) relate the material to be learned to what the student has already experienced, and thereby show him where the new materials fit into his previous experience, and (b) supply an internal organizational structure at a high level of generality for the material the student is about to read.

Using the above definition, two organizers were developed. One was a summary organizer, which is essentially the same as Ausubel's expository organizer, and the other was a question organizer designed to perform the same function as the summary organizer in a less directive manner.

The three treatments (information sheets) were identical in all respects except that the two experimental treatments each contained one variation of the organizer placed between the introductory motivational paragraph and the body of technical information, while the traditional treatment did not. Since Ausubel has hypothesized that the ability of an organizer to aid a person in learning verbal materials is affected by his ability and the difficulty level of the material encountered, the treatments were replicated on moderately difficult and difficult materials and the samples used were stratified according to ability.

Six random samples were drawn from the population of male, post-high school, full-time, day trade students at the Minneapolis Area Vocational-Technical School, with the exclusion of those enrolled in electronics, in such a way that each sample contained a sub-group of high ability and a sub-group of low ability students. The six samples were then randomly assigned to the three moderately difficult treatments (metalworking applications of the laser) and the three difficult treatments (communications applications of the laser). The treatments were administered along with the initial learning test, and six weeks later the retention and transfer tests were administered.

The three criterion measures (initial learning, retention and transfer) were each analyzed separately using a 2 x 3 x 2 three-way nested analysis of variance design.

Conclusions

The following conclusions are based upon the answers provided by this study to the questions posed in Chapter I, as "Objectives of the Study." The conclusions are based upon, and are limited to, the particular sample utilized and the conditions prevailing during the study, or to similar hypothetical populations and circumstances.

1. There were no significant differences between the three treatments using either moderately difficult or difficult material in terms of the amount of initial learning, retention or transfer.
2. No significant interactions were found between treatment and ability or between ability and difficulty for either moderately difficult or difficult materials in terms of initial learning, retention or transfer. As one would expect, in each analysis (initial learning, retention, and transfer) significant differences were found between the ability groups.

Discussion and Implications

The investigator proposes four possible reasons for the lack of differences found between the treatments used in the study. The first two reasons are probably contributory, while the last two are likely to be major causes.

First, the criterion tests used to measure differences between the treatments were not sufficiently sensitive. Although this reason may be significant in the case of the transfer tests, with reliabilities of .67 and .68, it does not appear as important in the case of retention tests, both of which had reliabilities of .81. Also before revision, the tests were sensitive enough to detect differences in the pilot study.

Second, the organizers used in the study were not developed correctly and, therefore, did not perform as an organizer. Although this reason is possible, the investigator does not feel it is too probable. The organization of the organizers, as well as the completed organizers, were judged by a purposive sample of educational psychologists and industrial educators who indicated that they thought the organizers did perform the functions specified by Ausubel in his writings and in his letter to Dawson.

Third, the initial learning questions at the end of each information sheet performed essentially the same function as the organizer. The investigator recognized prior to the study that the questions which constitute the initial learning test on the traditional information sheet might tend to nullify the effects of an organizer, but it was decided that, since the problem was to test the relative effectiveness of the traditional versus two modified versions of an information sheet, they must be included. If they had not been included the information sheets would not have represented typical information sheets, or if they were included but the students were not allowed to go back into the material to answer them, the method of utilizing information sheets would not have been typical.

Although it is plausible that the initial learning questions tended to nullify the effects of the organizer, the pilot study data tended to indicate that those groups receiving organizers did do better on a seven day retention test than those not receiving organizers.

Fourth, the time lapse between reading the information sheets and taking the initial learning test, and then taking the retention and transfer tests may have been too great. In the planning of this study the investigator decided to administer the retention and transfer tests six weeks after the first phase of testing. The reason was that in the practical application of information sheets retention and the ability to transfer after six weeks are important. Ausubel has used retention spans of from three to ten days in his studies. Although he found significant differences over those relatively short periods of time he has not tested longer term retention. There is evidence to support the contention that the obliterative effects of subsumption leading to forgetting tend to reduce the differences between groups receiving organizers and groups not receiving organizers. In Ausubel's study (12) comparing the effectiveness of the comparative and expository organizer (see page 13, Chapter I) it was found that the group receiving the comparative organizer retained significantly better than the group receiving the expository organizer after three days. However, after ten days there was no significant difference. This trend was also noted by the investigator in the present study when significant differences did occur in the pilot using a seven day retention span and not in the principal study after six weeks. Since the present study was designed, Dawson's dissertation (19) has been completed; he also substantiates this trend (p. 14, Chapter I). Using the same test, he found significant differences in initial learning and retention after three weeks, but he did not find significant differences at five weeks. In other words, although organizers may aid individuals initially, their long term value is questionable.

Since neither this study nor Dawson's study was designed to test specifically the decreasing efficiency of an organizer, perhaps the most fruitful outcomes are the clues they provide for further investigation. Some of these clues are presented below as relevant questions.

1. Does the effectiveness of an organizer decrease over time to the point where the time and energy spent in developing it are not warranted? If so, what is this time span?
2. Would well selected essay type questions placed at the end of relatively short sections of written materials, which students are required to answer, perform the same function as an organizer?
3. Can more adequate operational definitions be developed to aid in the construction of organizers?
4. Can simpler, more effective organizational principles be developed to aid in the organization of verbal information than those proposed by Ausubel?

Although clues have been unveiled as possible limitations in the practical application of Ausubel's "Subsumption Theory of Meaningful Verbal Learning and

Retention," the theory should be explored further. It represents one of the promising attempts which are currently being made to deal with the practical aspects of human verbal learning, and therefore deserves to be thoroughly investigated.

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APPENDIX A

BLUEPRINTS OF CONCEPTS CONTAINED IN EACH INFORMATION SHEET AND THE ITEMS TESTING EACH CONCEPT

A-1 Metalworking Blueprint

A-2 Communications Blueprint

APPENDIX A-1

BLUEPRINT OF THE CONCEPTS AND ITEMS TESTING EACH CONCEPT (METALWORKING)

	RETENTION*	TRANSFER**
A. Laser production tools are not available (Shop experience is totally lacking)	26	48
B. First solid-state laser 1960		
C. Three types of lasers	10	
1. liquid-beginning stages		
2. gas-beam too weak		
3. solid-state (used most because of greater power potential)	37, 44	65, 68
D. Generation of a laser beam		
1. components		
a. flash lamp is wound around the ruby rod	14	
b. synthetic ruby rod	32	
c. capacitor which excites the gas in the tube and therefore the ruby rod		70
1. stores electrons	5	
2. discharges them in a powerful surge	13	
2. reason for pulse type emission (recharging capacitor)	24, 30	

*The rentention items have been constructed to satisfy the definition presented in Bloom's, Taxonomy of Educational Objectives (Cognitive Domain) of items which test "knowledge." "Knowledge as defined here includes those behaviors and test situations which emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena" (15, p. 62).

**The transfer items have been constructed to satisfy the definition presented in Bloom's, Taxonomy of Educational Objectives (Cognitive Domain) of items which test "application." "The application category follows this rule,... to apply something requires 'comprehension' of the method, theory, principle, or abstraction applied..." "Given a problem new to the student, he will apply the appropriate abstraction without having to be prompted as to which abstraction is correct or without having to be shown how to use it in that situation" (15, p. 120).

	RETENTION	TRANSFER
3. energy in an atom		
a. usually at its lowest level	31	66
b. can be raised by absorbing external energy (photons)	16	56, 60
4. chain reaction of photons between chromium atoms	2, 23	
a. loss of non-parallel energy	21	
b. magnification of parallel energy		46, 57,55
5. breaking-out of the beam of high intensity light (mirror coating lighter on escape end)	17, 25	64
E. Characteristics of the laser beam		
1. directional	3, 22	
2. energy surpasses the sun		62
F. Energy is concentrated by focusing the beam using lenses	1, 11	63
G. Conversion of the light beam to heat	9, 19	47, 58
1. opaque absorbative material	4	
2. opaque reflective material	18	
H. Primary methods of metal manipulation with the laser	36, 38	54, 49
1. melting		
2. vaporizing		
I. Laser energy re-directed with mirror	12, 40	
J. Rapidity of heating action and chemical reactions (oxidation)	27	
K. Micro-applications		
1. welding	7	
2. machining	42	
3. spectrum analysis	39	59
L. Advantages of the laser in welding		
1. can melt all metals	28	52
2. can operate in any atmosphere	20, 34	
3. can be focused quickly and accurately	6	
4. short heat duration prevents oxidation and distortion	29, 45	61

	RETENTION	TRANSFER
M. Comparison of electron beam welding and laser welding	33,15	50,67
N. Penetration of the laser beam		51
1. does not penetrate	43	
2. heats by conduction from the outside in		
O. Machining	41	
1. vaporizes the material	35	
2. can be highly focused		69
3. material machined is removed from the work area	8	
P. Spectrography		
1. doesn't destroy piece being analyzed		
2. vaporizes the metal		
Q. General		53

APPENDIX A-2

BLUEPRINT OF THE CONCEPTS AND ITEMS TESTING EACH CONCEPT (COMMUNICATIONS)

	RETENTION*	TRANSFER**
A. Generation of laser light		
1. lasers generate high intensity light (diamond drilling)		50
2. the light is produced as a beam	3	
3. most common method of laser generation		
a. by means of a chain reaction	13	
b. chain reaction occurs within an artificial ruby rod	18	
B. One laser beam can carry the voices of more than four times the population of the U.S. simultaneously		
C. Use of light to carry meaningful signals		
1. not new		
2. first sent by reflected sunlight	24	
3. voice signals were transmitted by Alexander Graham Bell in 1880's using focused light		

*The retention items have been constructed to satisfy the definition presented in Bloom's, Taxonomy of Educational Objectives (Cognitive Domain) of items which test "knowledge." "Knowledge as defined here includes those behaviors and test situations which emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena" (15, p. 62).

**The transfer items have been constructed to satisfy the definition presented in Bloom's, Taxonomy of Educational Objectives (Cognitive Domain) of items which test "application." "The application category follows this rule,... to apply something requires comprehension' of the method, theory, principle, or abstraction applied... Given a problem new to the student, he will apply the appropriate abstraction without having to be prompted as to which abstraction is correct or without having to be shown how to use it in that situation" (15, p. 120).

	RETENTION	TRANSFER
D. How sounds are produced and heard		55
1. words or sounds create waves or differences in air pressure	31	
2. the waves travel through the air much as waves over water		
3. the waves are received by the ear	32	
4. the waves are interpreted by the mind	23	
E. Nature of the telephone		56,60
1. picks up difference in air pressure caused by sounds		
2. converts the difference in air pressure into differences in electrical energy	25	
3. at the receiver the differences in electrical energy are converted back to differences in air pressure	4	
F. Providing we can deliver the original differences in air pressure, we are free to dismantle it in any way we see fit.	20	67,68
G. Amplitude modulation		66,63
1. transmitter		61
a. voice signal-represents the conversation to be transmitted	27	
b. carrier wave		
c. modulator		
d. voice signal is combined with the carrier wave in a modulator		
e. the combined waves produce two new frequencies		59
1. sum of the two waves	6	
2. difference between the two waves		
f. only one of the two new frequencies is needed to transmit the signal		
g. the unused frequency is filtered out	33	49

	RETENTION	TRANSFER
2. receiver		51,57
a. same frequency carrier wave as used in transmitter	11	
b. the transmitted frequency (new wave frequency)		
c. a second modulator	17	
d. the same frequency carrier wave is combined with the transmitted frequency in the modulator to produce the original voice frequency	30	52
H. Bandwidth necessary for one voice (voice signal ranges from a few cycles to about 4,000 cps.)	22,38	62
I. Sending a second simultaneous voice signal		
1. a second carrier wave at a frequency outside the bandwidth of the first carrier wave		
2. second voice signal		
3. second modulator		
4. as long as the second bandwidth does not overlap that of the first the two voice signals can travel independently	19,36	48
J. The sending of multiple voice signals requires adequate bandwidth		64
1. a bandwidth of 4,000 cps is needed for each voice signal	15	
2. ten voices require 40,000 cps for bandwidth		
K. Relationship of efficiency and transmitting frequency		
1. the higher the frequency the lower the efficiency	16,35	58
2. part of the high frequency energy is lost as heat		53
L. Need for amplifying telephone signals		

	RETENTION	TRANSFER
1. as energy is lost in the form of heat, the signal becomes weaker	12	54
2. telephone signals are amplified every 4 miles	3	
M. History of the carrier technique	8	
1. Bell telephone system used it in 1918 to transmit four voices over a pair of wires		
2. cables in 1930's	14	46,70
a. wider usable band		
b. 12 voice signals can be sent over each pair of wires		
3. coaxial conductors	28	
a. construction reduces tendency for heat damage	21,34	
b. much wider usable band		
N. Advantages in using the laser rather than conventional techniques		
1. extremely large bandwidth		
a. high frequencies	45	
b. constant frequencies	29	
c. can be used with the carrier technique	9	
2. extremely powerful and directional		
a. a laser beam is more intense than the sun	10	65
b. laser light naturally emerges as a highly directional beam		
O. Contrast between laser light and light from an ordinary source such as a light bulb	7	
1. Laser high and very pure frequency, very intense, highly directional, can be used with carrier technique	2,40	47,69
2. Ordinary sources high frequency but not pure, not intense, radiates in all directions, cannot be used with the carrier technique	37,43	

	RETENTION	TRANSFER
P. Potential uses of laser bandwidth		
1. voice signals	26	
2. TV signals (take 1,000 times more frequency than voice signals)		
3. computer digital pulses	5	
Q. Practical limitations of laser communication		
1. need to protect the beam		
a. diffusion due to mist or smog		
b. blocking due to rain or snow	42	
2. pipe transmission to protect the beam	41	
3. necessity of keeping beams pointed in the proper direction despite distortion due to heat and vibration (prisms, mirrors, lenses)	44	
4. Lenses concentrate the beam		
5. Mirrors re-direct the beam		

APPENDIX B

THE INFORMATION SHEETS

B-1 Metal working Information Sheet
  Directions
  Traditional Introduction
  Traditional Introduction Plus Summary Organizer
  Tratitional Introduction Plus Question Organizer
  Body of Information Sheet
  Initial Learning Test

B-2 Communications Information Sheet
  Directions
  Traditional Introduction
  Traditional Introduction Plus Summary Organizer
  Traditional Introduction Plus Question Organizer
  Body of Information Sheet
  Initial Learning Test

APPENDIX B-1

Metalworking Information Sheet

NAME__________________________________NUMBER____________

PROGRAM ENROLLED IN___________________________________
(e.g. welding, drafting, cabinet
making, etc.)

AGE______________ SEX M ☐ F ☐
(check one)

DIRECTIONS

Read and study the following information concerning the laser and answer the six test questions at the end of the material on the blank pages provided. Read the introduction especially carefully for it will further your understanding of the later material. An attempt is being made at determining how well a group of persons enrolled in vocational courses can read and understand technical material.

Scores will be posted according to the number found on the upper right hand corner of this page which will allow you to compare your score with those of your classmates.

TRADITIONAL INTRODUCTION

The laser is a device which appears to have come directly from a Buck Rogers comic strip. Although it is often thought of as a high energy light beam with few practical applications, scientists predict unlimited uses for laser beams in the future. Applications are predicted in many areas of vocational education such as electronics, metallurgy and photography. Since persons training for an occupation must be aware of possible future developments within that occupation, the future uses of the laser are of great concern. A current example of the possible introduction of the laser into an occupational area is its use in metalworking. Lasers emit the most intense radiant energy known to man, and hence, may revolutionize metal-processing techniques within the next five years. Specialties like microwelding, micromachining and metallurgy are but a few of the fields that will feel the impact. Developments of this type will not only affect occupations concerned with metalworking but also many related occupations.

TRADITIONAL INTRODUCTION PLUS SUMMARY ORGANIZER

The laser is a device which appears to have come directly from a Buck Rogers comic strip. Although it is often thought of as a high energy light beam with few practical applications, scientists predict unlimited uses for laser beams in the future. Applications are predicted in many areas of vocational education such as electronics, metallurgy and photography. Since persons training for an occupation must be aware of possible future developments within that occupation, the future uses of the laser are of great concern. A current example of the possible introduction of the laser into an occupational area is its use in metalworking. Lasers emit the most intense radiant energy known to man, and hence, may revolutionize metal-processing within the next five years. Specialties like microwelding, micromachining and metallurgy are but a few of the fields that will feel the impact. Developments of this type will not only affect occupations concerned with metalworking but also many related occupations.

Metal is a material all of us are familiar with. Since different metals have different properties, terms such as hardness, brittleness, and tensile strength are used to describe them. The given combination of these characteristics must be known before a metal is processed.

Metal processing is done by shaping (cutting), forming (bending), and joining. The most common metals, such as those containing iron, have common characteristics which lend them to processing techniques using heat. For example, cutting steel with a cutting torch or joining steel with a welder. In such metalworking operations heat is usually generated by chemical reactions (burning of gas in a gas torch used in cutting or welding steel) or electrically (cutting with an electric arc or welding with an electric welder). Although chemically and electrically generated heat have been used in the past, metallurgy has produced more durable metals and technology has demanded more accuracy in metal processing; present methods no longer are adequate for these new metals and demands. Consequently, more precise methods using higher intensity heat are being developed. One of these utilizes the laser. The laser produces a very high intensity light beam generated by a chain reaction stimulated by electrical energy. This energy is converted to heat and applied to machining, welding, and spectrum analysis as indicated in the following information.

TRADITIONAL INTRODUCTION PLUS QUESTION ORGANIZER

The laser is a device which appears to have come directly from a Buck Rogers comic strip. Although it is often thought of as a high energy light beam with few practical applications, scientists predict unlimited uses for laser beams in the future. Applications are predicted in many areas of vocational education such as electronics, metallurgy and photography. Since persons training for an occupation must be aware of possible future developments within that occupation, the future uses of the laser are of great concern. A current example of the possible introduction of the laser into an occupational area is its use in metalworking. Lasers emit the most intense radiant energy known to man, and hence, may revolutionize metal-processing techniques within the next five years. Specialties like microwelding, micromachining and metallurgy are but a few of the fields that will feel the impact. Developments of this type will not only affect occupations concerned with metalworking but also many related occupations.

Answer the following questions to the best of your ability before reading the information on the laser.

Metal is a material all of us are familiar with. Since there are many kinds of metal, they are described by characteristics. What are some of these characteristics?

The characteristics of metal must be known before the metal can be processed or changed in some way. What processing techniques are used on metal? The most common metals, such as those containing iron, have common characteristics which lend them to processing techniques using heat. By what means is heat commonly generated for cutting and joining metal?

Science has made it possible to produce more durable metals, and technology has demanded more precise ways of processing them. The old methods of heat processing are no longer adequate. New, more precise and higher intensity methods of heat generation are being developed. One of these is the laser. The following material will help you answer the questions: How does the laser generate heat? How intense is the heat? How is this heat applied to metalworking?

BODY OF INFORMATION SHEET

THE LASER

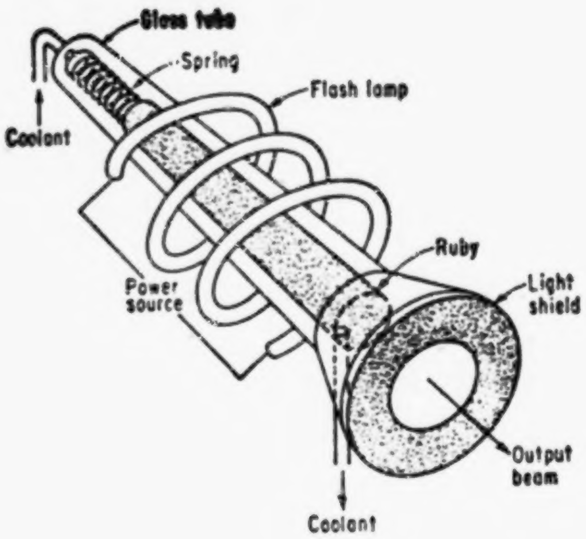
Since the Research Laboratories of the Hughes Aircraft Company developed the first practical solid-state laser in 1960, many technical papers have been written defining the fundamental principles in typical scientific language. However, laser production tools are not yet available and actual shop experience with them is totally lacking. Fortunately, the laboratory data available today are so comprehensive that predictions can be made concerning those areas of metalworking to which the laser will be most applicable in the near future.

There are three types of lasers being developed at this time-- these are liquid, gas and solid-state lasers. Liquid lasers are not of immediate importance because they are in their beginning stages of development. The gas laser has reached a somewhat higher state of development, but the beam produced with present equipment is so weak that it is not practical to apply it to metalworking techniques.

The third type, the solid-state laser, is used in most of the experimental metalworking and metallurgical investigations being conducted at this time because solids contain more active atoms per square inch than do liquids or gases and therefore, can generate a more powerful laser beam with a smaller laser device. The basic features of a solid-state laser are shown in Figure 1.

A flash lamp filled with a special gas is wound around a glass tube surrounding a synthetic ruby rod. One end of the glass tube is shaped like the muzzle of a gun to allow a laser beam to emerge, while the rest of the glass tube forms a cylinder around the ruby rod through which a coolant is circulated for temperature control. A spring is used to hold the ruby rod in place.

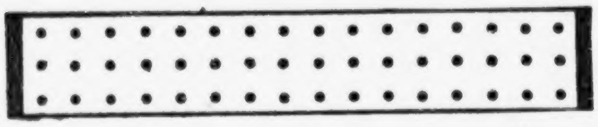
Figure 1



The gas in the flash lamp is activated or fired by the discharge of a capacitor located inside the power source. A capacitor is an electronic device which is charged much the same as a car battery and can store a large amount of electrons on metal plates. When the capacitor is discharged, the stored electrons surge from the capacitor and activate the gas in the flash lamp which then emits streams of energy called photons.

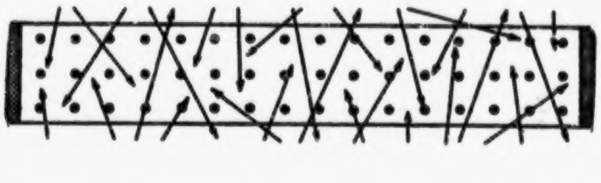
Physicists tell us that atoms, which make up all substances, have internal energy and that they are normally at their lowest possible energy level. (Figure 2)

Figure 2



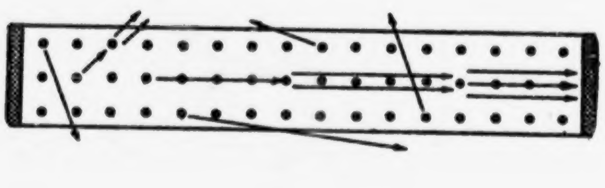
These atoms can be raised to a higher level of energy by absorbing energy from another source. In the case of the laser this other source is the photons emitted by the excited gas in the flash lamp. The synthetic ruby rod contains chromium atoms which are excited when the photons of energy from the flash lamp enter the ruby rod and strike them. In this excitement some of the chromium atoms also begin to emit photons. (Figure 3)

Figure 3



If the photons of energy in the ruby rod are emitted or released in any direction except parallel to the length of the ruby rod, they merely pass through the rod wall and are lost. If the photons travel parallel to the rod's length, they soon collide with other chromium atoms. (Figure 4) When this collision occurs, the bombarded atom

Figure 4



is stimulated to emit a photon of its own energy which travels in the same direction as the photon emitted by the first chromium atom. We now have two photons traveling along together. Before long these two photons will strike two more chromium atoms, and, following the pattern just described, four photons will result. The four photons will eventually strike other atoms and result in eight photons, and so the chain reaction will continue until there is a tremendous build-up of energy within the ruby rod.

Both ends of the ruby rod are mirror-coated allowing accumulated photons to be reflected back and forth through the length of the rod as the chain reaction continues. (Figure 5) One end of the ruby rod (the laser escape end) has a thinner mirror coating than the other. When the photons of energy in the rod reach a critical point, they will suddently burst through the thinner mirror coating and through the muzzle of the laser device in the form of a useful laser beam of high intensity light. (Figure 6)

Figure 5

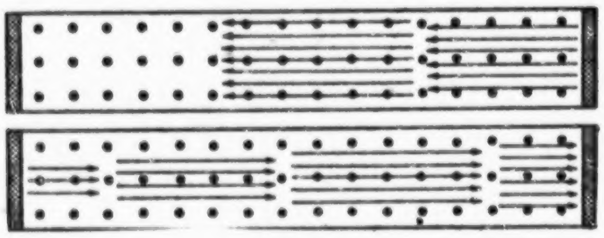
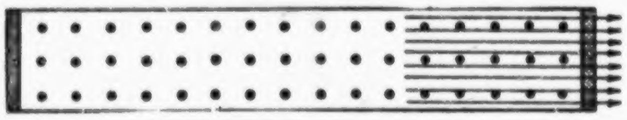


Figure 6



After this single breakthrough, or pulse of laser energy, the entire process must be repeated before another beam is generated because the capacitor has been discharged and must be recharged. Thus, the beam produced by a ruby laser is a pulse type rather than a continuous beam.

A laser beam spreads very little after it finally emerges. The huge number of photons generated by the chain reaction results in a beam of light energy no larger than the diameter of the ruby rod. Beams produced by ruby lasers have achieved energy levels per square inch exceeding those produced by the sun.

For metalworking and metallurgical applications, the energy of the laser beam is concentrated by using a system of lenses which concentrate the beam to a point no larger than a speck of dust. In order for the beam to be useful in metalworking, it must be transformed from light energy to heat energy. When a laser beam is focused by lenses on a material that is opaque, or will not allow the beam to pass through, the light energy is changed to heat energy upon striking the object. For example, if the beam strikes a rock the light energy would be transformed into heat energy because it could not pass through the rock. However, if the beam strikes a piece of clear glass, the light would pass through without being converted to heat. The temperature reached at the focus point on an opaque object is high enough to melt and vaporize every known material. In many cases, the temperature is between 10,000 and 16,000 degrees Fahrenheit. The higher temperatures are reached when the beam strikes materials which absorb the heat energy readily, such as a black-iron pot.

The lower temperatures are reached when the beam strikes opaque reflective materials, such as a mirror. In the case of the mirror, much of the heat energy is reflected off the surface, but in the case of the black-iron pot, most of it is absorbed. This explains why a mirror can be used to reflect and re-direct a laser beam without being destroyed.

The heat effects of a laser beam on metal can be closely limited with proper controls. The laser bursts occur so fast and produce heat so rapidly that chemical reactions which occur with conventional welding methods cannot get started. For example, oxidation, which is the reaction of oxygen in the air and hot metal, forms an undesirable coating on metal similar to rust which presents many problems in welding and machining. Since the laser burst occurs almost instantaneously, there is not enough time to allow the oxidation reaction to take place.

Initial applications of lasers on the production line will undoubtedly be for very small and delicate micro-operations. Some of these uses are microwelding, micro-machining and spectrum analysis of metallic materials. Welding is the process of joining two pieces of the same type of metal by heating and fusing them together (joining two steel beams). Machining represents the operations performed by machines on metal (drilling a hole in metal). Spectrum analysis is the process of vaporizing a small amount of a given metal and viewing this vaporized metal through a spectroscope in an effort to determine the composition of the metal (identifying the chemical elements in steel). In microwelding applications the laser will be controlled so that melting takes place with minimum vaporization. In micromachining work, and in the spectrum analysis of materials, the metal will be vaporized.

Microwelding applications of the laser have been developed more than other apparent uses. The laser is an excellent source of heat energy for welding for the following reasons.

1. The laser is a source of extremely high intensity energy, and under proper conditions should be capable of fusing all metals.
2. The laser can operate in any atmosphere ranging from ordinary air to inert gases or in a vacuum.
3. The laser beam can be quickly and accurately focused through the use of lenses to a very small spot.
4. The extremely short duration of the laser burst may prevent many of the undesirable factors accompanying the intense heat generated in conventional welding, such as oxidation and the distortion of metal.

In comparing laser microwelding with currently available microwelding methods, some of these advantages become even more apparent. In electron beam welding, for instance, the work must be done in a vacuum chamber. This puts definite limitations on the size of the parts that can be welded because of the problems involved in obtaining a vacuum within the chamber. Also, electron beam welding is restricted to metals which do not vaporize readily at their fusion temperature in a vacuum.

Having no penetration power, the laser beam heats from the surface inward by conduction. Therefore, with proper controls, the heat generated can be confined to extremely thin deposits of metal without affecting other layers of metal beneath. This is important in the manufacturing of solid-state electronic devices such as transistors containing thin metal components. Wires must be welded to these thin metal films without affecting the insulation that separates them.

Though less experimental work has been done in the area of micromachining, the characteristics of solid-state laser operation will allow some predictions. The small focus spot, plus the fact that the metal actually being cut is vaporized and removed from the work area, thereby eliminating the chips of metal commonly associated with machining, makes it possible for lasers to machine small high-precision holes.

The ability of a focused laser beam to vaporize extremely small amounts of metal allows metallurgists to determine the composition of a metal through spectrum analysis. The amount of vapor formed is sufficient to determine the composition of the piece under test, yet so small that it does not affect the work-piece in any way. A modification of this method could be used to test the skin of space vehicles for their resistance to re-entry temperatures and other high-temperature occurances encountered in flight.

In conclusion, it is not difficult to see from the results of laboratory experiments that the laser has many potential applications in welding, melting and machining. Further studies are in progress to develop methods and equipment to use this new source of energy for other metallurgical purposes. There seems to be little doubt that a high-energy continuous output laser will be developed and that such a tool will be far more usable than the pulse type in use today.

INITIAL LEARNING TEST

PLEASE ANSWER THE FOLLOWING QUESTIONS IN THE SPACE PROVIDED BELOW

1. Which of the three types of lasers is used most? Why?
2. Why does the laser give pulses of energy rather than a continuous beam?
3. Does all of the energy produced by the laser generator emerge as the laser beam? Why?
4. What is the difference between spectrum analysis and welding with the laser in terms of what is done to the material being processed?
5. What type of atmospheric conditions must exist before the laser can be used as a metalworking tool?
6. What devices are used to direct and focus laser beams?

APPENDIX B-2

Communications Information Sheet

NAME____________________________________NUMBER______________

PROGRAM ENROLLED IN____
(e.g. welding, drafting, cabinet making, etc.)

AGE________________ SEX M ☐ F ☐ (check one)

DIRECTIONS

Read and study the following information concerning the laser and answer the six test questions at the end of the material on the blank pages provided. Read the introduction especially carefully for it will further your understanding of the later material. An attempt is being made at determining how well a group of persons enrolled in vocational courses can read and understand technical material.

Scores will be posted according to the number found on the upper right hand corner of this page which will allow you to compare your score with those of your classmates.

TRADITIONAL INTRODUCTION

The laser is a device which appears to have come directly from a Buck Rogers comic strip. Although it is often thought of as a high energy light beam with few practical applications, scientists predict unlimited uses for laser beams in the future. Applications are predicted in many areas of vocational education such as electronics, metallurgy and photography. Since persons training for an occupation must be aware of possible future developments within that occupation, the future uses of the laser are of great concern. A current example of the possible introduction of the laser into an occupational area is its use in communications. Communications engineers foresee the day when laser beams, rather than wires, will be used to send communications signals. A development of this type will not only affect occupations concerned with communications but also many related occupations.

TRADITIONAL INTRODUCTION PLUS SUMMARY ORGANIZER

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All of us communicate with others every day. This communication usually takes the form of speech, symbols or signs. In order for people to communicate over long distances commercial devices have been developed. Some of these devices are the telephone, telegraph and radio. Most long range communications devices carry signals from one point to another utilizing electricity. For example, voices are changed into electricity by a telephone, transmitted over wires, micro-waves or some other means of carrying electrical signals, and then reconverted to voices at another place.

Although present techniques have been capable of handling the volume of communications in the past, this volume has been growing rapidly and present devices are nearly at the practical limit of their capacity. This is because present communications devices are limited in the number of voice (electrical) signals that can be transmitted at the same time and the need to amplify the voice signals every few miles. The laser provides a potentially more efficient vehicle for voice signal transmission due to the extreme power of the laser, and the large number of voice signals that can be sent over one laser beam. Communications engineers hope that the laser may overcome many of the limitations of present communications devices. The following information provides details on how this may be done.

TRADITIONAL INTRODUCTION PLUS QUESTION ORGANIZER

The laser is a device which appears to have come directly from a Buck Rogers comic strip. Although it is often thought of as a high energy light beam with few practical applications, scientists predict unlimited uses for laser beams in the future. Applications are predicted in many areas of vocational education such as electronics, metallurgy and photography. Since persons training for an occupation must be aware of possible future developments within that occupation, the future uses of the laser are of great concern. A current example of the possible introduction of the laser into an occupational area is its use in communications. Communications engineers foresee the day when laser beams, rather than wires, will be used to send communications signals. A development of this type will not only affect occupations concerned with communications but also many related occupations.

Answer the following questions to the best of your ability before reading the information on the laser.

All of us communicate with others every day. How do we communicate? In order to communicate with persons over long distances, commercial devices have been developed. What commercial devices are used to aid in long distance communication? Most of these long range devices carry signals from one point to another utilizing electricity.

Although present communications techniques have been sufficient to handle the volume of communications in the past, this volume has been increasing rapidly and present devices are having difficulty keeping up with this increasing demand. The following material will help you answer the questions: How are voices changed into electrical energy, transmitted and reconverted to voices at another place? What are the limitations of present long distance voice communications systems? How can the laser aid communications engineers in overcoming present difficulties in long distance voice communications systems?

BODY OF INFORMATION SHEET

THE LASER

The laser is a device designed to generate very high intensity light beams capable of burning holes through diamonds. Energy is built up within a synthetic ruby rod by means of a chain reaction and released in the form of a beam of light when the energy within the rod reaches a critical point.

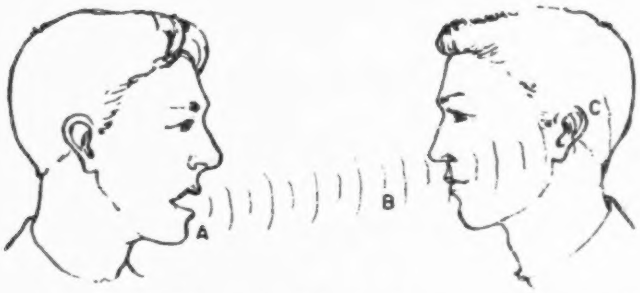
One of the applications of the laser which has caught the popular imagination is its ability to carry large amounts of information at the same time. One laser beam is capable of transmitting the voices of more than four times the population of the United States at the same time.

The use of light to carry meaningful signals and speech is not new. Thousands of years ago light was used to send coded signals by reflecting sunlight from a polished surface. As far back as the 1880's Alexander Graham Bell demonstrated the transmission of voice signals by means of focused light beams. The startling thing about lasers lies not in the fact that they can carry voice, but rather in the fantastic number of voices they can carry at the same time.

If we can see how two voices can share a wire circuit (telephone wires) or a radio beam at the same time without interfering with each other, then it is a simple matter of arithmetic to see why it is possible to make a billion voices share a beam. Let us start by observing the process of communicating by speech.

In talking, each sound uttered creates differences in air pressure (or sound waves) which travel through the air much as waves travel over water. These differences in pressure are received by the ear drum and interpreted as sounds or words by the mind. (Figure 1)

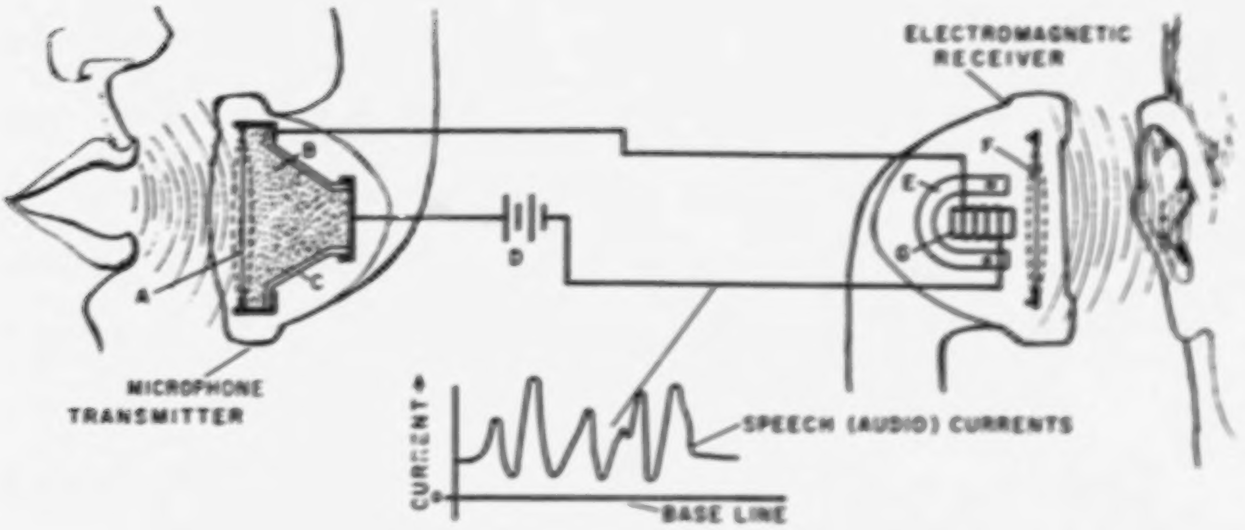
Figure 1



Talking to a friend: (A) transmitter (mouth and throat), (B) carrier (air molecules), (C) receiver (ear).

The section of a telephone we speak into must be designed to receive these differences in air pressure as we speak, dismantle them, and transmit them as differences in electrical energy from one place to another. At the receiver, the telephone must assemble the differences in electrical energy and produce the original differences in air pressure so that the listener can hear what has been said. (Figure 2) As long as the original differences in

Figure 2



air pressure that are formed when we speak can be delivered to the listener, what happens between the time we speak and the listener hears is of little consequence. Therefore, providing the original voice pattern of differences in air pressure can be delivered to the listener, they can be dismantled or otherwise manipulated. It is through such manipulation that many voice signals are fitted in with each other to travel over the same pair of wires. One such technique is known as amplitude modulation.

To transmit by means of amplitude modulation, the voice signal (in the form of varying electrical energy) together with a specially generated carrier wave, is fed into a device known as a modulator. The modulator takes each wave in the voice signal and combines it with that of the carrier to produce two new waves. One of the new waves has a frequency (the number of cycles or vibrations the wave undergoes each second) equal to the sum of the carrier wave frequency plus the voice wave frequency. The other new wave has a frequency equal to the carrier wave frequency minus the voice wave frequency. Thus, if a voice tone with a frequency of 256 cycles per second (cps) is fed into a modulator along with a carrier frequency of 50,000 cps, the modulator combines the two producing two new frequencies. One of these is the difference between the two frequencies or 49,744 cps and the other is the sum of the two frequencies or 50,256 cps. Although the 50,256 cps frequency will be used in the following example as the transmitted frequency, either of the two new frequencies could be used to transmit the voice signal from one place to another, but since we only need one, the other is "filtered out" or removed.

At the receiver, we have another 50,000 cps carrier wave generator and a de-modulator. The incoming 50,256 cps frequency combines with the 50,000 cps frequency in the de-modulator to produce 256 cps -- the original voice tone frequency. As we speak our voice pattern has tonal (frequency) changes from as low as a few cycles (low tones) to as high as 4,000 cycles (high tones). Therefore, at each instant, the modulator combines its 50,000 cps carrier wave with incoming wave frequencies which may occur anywhere in a band extending from 50,000 cps to 54,000 cps.

A second voice signal may be sent over the same wires at the same time by modulating it with a second carrier wave at 54,000 cps. In this way the second voice signal can be made to travel in the frequency band ranging from 54,000 cps to 58,000 cps, here it can exist as privately as though the first voice were not there. Thus, two voice signals may be sent at the same time in the range from 50,000 cps to 58,000 cps. Given a third carrier frequency, a third voice signal can be sent along with the first two in the range from 58,000 cps to 62,000 cps, etc.

The sending of many signals together demands adequate frequency bandwidth. Each voice requires its own separate 4,000 cps. If we want to send ten voices, we need 40,000 cps of bandwidth. This also means that a separate carrier wave generator would be needed to transmit one voice signal in each of the ten sub-bandwidths of 4,000 cps (4,000, 8,000) etc. If sufficient bandwidth is not provided for each voice signal, the signals overlap causing interference much the same as having a radio tuned to two stations at the same time. Since bandwidth increases if the lower frequency of the band remains the same and the upper frequency of the band is increased, wider bands are obtained by increasing the upper frequency. For example, the bandwith between 12,000 cps and 52,000 cps is wider than the bandwidth between extending from 50,000 cps to 54,000 cps.

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12,000 cps and 22,000 cps. However, when the operating frequency of a signal transmitted over a conductor such as a wire is increased, part of the energy of the high frequency waves turns into heat and the efficiency of the wire circuit is reduced. The higher the frequencies, the greater the reduction of efficiency. To make wires carry many voices simultaneously, to achieve ever-wider usable bands, communication engineers must engage in a constant struggle with these high-frequency losses. As an example, assume that a voice signal is picked up in New York for transmission over a 3,200 mile telephone circuit to San Francisco. The wire loss is never allowed to become significant. Every 4 miles the voice signal is sent through a relay station and amplified to strengthen it, because of high frequency losses. In its journey from New York to San Francisco the signal passes through approximately 800 amplifiers.

The practicality of the carrier technique was demonstrated in 1918 when the Bell Telephone System transmitted four voices over a pair of wires at the same time. Each pair of wires operated from a minimum of 12,000 cps to a maximum of 60,000 cps, thus providing a band 48,000 cps wide. Twelve voices (48,000 divided by 4000) could be sent over each pair of wires. In the 1930's it became possible to apply the carrier techniques to cables containing many separate wires under one protective coating.

Later came the development of a type of conductor in which a wire runs coaxially or within a pencil-sized metal tube. These are called coaxial conductors, and permit a band width of up to 8,300,000 cps, since coaxial conductors are not as subject to destruction due to heat generated by high frequencies as are ordinary wires. Theoretically 2,075 conversations can be transmitted over two coaxials simultaneously. However, in practice only 1,800 are usually transmitted because of practical limitations.

Communications engineers hope that the laser will overcome some of the limitations of the wire and coaxial systems. One such difficulty is that of achieving adequate bandwidth. Very high frequencies generated by lasers indicate that the communications bandwidth of the laser beam is very wide. High frequencies generated by ruby lasers typically range from 400,000,000,000,000 to 400,006,000,000,000 cps, which provides for many carrier waves spaced 4,000 cps apart.

Ordinary light sources, such as an electric light bulb, also generate relatively high frequencies, but they cannot be used because the light from an ordinary light source is a combination of frequencies and colors. The carrier technique requires that each carrier wave be constant in frequency in order to prevent one conversation from interfering with another. Laser light, on the other hand, is relatively constant in frequency and color and, therefore, can be used with the carrier technique.

Amplification problems will also be reduced by using a laser beam. The laser can be transmitted great distances with an intensity per square inch surpassing that of the sun. Contrasted with light from an ordinary source, which radiates in almost every direction, laser produced light is extremely directional. Reflectors and lenses are necessary in order to concentrate ordinary lamp light into a beam. Laser light naturally emerges as a beam with such nearly parallel rays that they spread less than 5 inches per mile. Since the beam is powerful and highly directional, it can travel long distances with no amplification.

The prospects of using laser beams as communications tools are spectacular, although we do not yet have enough experimental data to predict reliably what percentage of the frequency can be used. Nevertheless, to form an idea, we might assume that a laser beam system could be designed to use its available frequency in much the same way that microwave systems do today. Therefore, applying microwave theory to what we know about lasers the number of voice signals a laser system might carry comes out to be 800,000,000; this is more than four times the present population of the United States. It is unlikely that a laser beam will be called upon to transmit almost a billion voices at the same time, even if it turns out to be possible.

Frequency bandwidth is like a dollar bill, which provides a specific amount of credit. You can spend a dollar bill in more than one way--to buy, let us say, one-hundred one-cent items or four 25-cent items. Different types of signals also have varying "prices" in terms of bandwidth. Each voice transmission needs 4,000 cps, but a TV program is high-priced, requiring a 4,000,000 cps bandwidth-- 1,000 times as much as is needed for a voice. Because information in a moving picture changes 1,000 times more rapidly than in a voice, a thousand voice signals can be exchanged for one TV picture.

Communications engineers generally do not think of voices or TV pictures as efficient users of this large laser bandwidth. They think of a circuit as being able to transmit a specific number of "yes" or "no" bits of information per second. Since this is the language of computers, the transmission of computer data will probably provide the laser with its greatest opportunity in communications. A wide bandwidth is required to send computer information in the form of digital pulses rapidly. Just as you can trade voices for TV pictures, you can trade either or both for high-speed transmission of computer information. The time may come when a computer on the east coast of the United

States, having completed a series of massive calculations and "wishing" to communicate the facts to its mate on the west coast, would simply dial the appropriate number, then transmit a detailed account of the problems together with the answers in less time than it takes to wink an eye.

Although we know the laser has the ability to travel considerable distances through space without losing its energy, light is scattered by mist and smog. Heavy rain or snow can completely blot it out. Therefore, it is necessary to protect the laser beams in order to operate a reliable day-and-night commercial communications system regardless of weather. Transmission through pipes filled with a special gas has been suggested. However, pipe transmission involves its own special difficulties. The basic problem is controlling the transmitted signal so that it is not seriously distorted. Another problem is that of keeping the beams pointed in exactly the right direction despite the physical distortion of parts due to changes in heat or vibration. Lenses and mirrors might be used to take the beams around corners or to follow the earth's contour. Since laser beams are a form of light, lenses can be used to periodically re-concentrate he beam into a narrower beam and the mirrors can be used to re-direct it.

Transmission over long distances with the laser poses many engineering difficulties. However, communications engineers are confident that these problems can be solved.

INITIAL LEARNING TEST

PLEASE ANSWER THE FOLLOWING QUESTIONS IN THE SPACE PROVIDED BELOW

1. The modulator produces two new waves; what combinations of the voice and carrier wave frequencies do these represent?
2. Why must 4,000 cps of bandwidth be allowed for each voice in multiple voice transmission?
3. Why are high frequency circuits less efficient than low frequency conductor circuits?
4. How is a laser beam generated?
5. Why is it possible to use the carrier technique with laser light and not with ordinary light?
6. Why is it theoretically possible for the laser beam to carry so many conversations at the same time as compared with conventional methods?

APPENDIX C

RETENTION AND TRANSFER TESTS

C-1 Metalworking Tests
  Directions
  Retention Test
  Transfer Test

C-2 Communications Tests
  Directions
  Retention Test
  Transfer Test

APPENDIX C-1

Metalworking Tests

NAME______________________________NUMBER____________

DIRECTIONS

About six weeks ago you read some information concerning lasers and answered six questions. Those questions were designed to see how well you could remember technical information immediately after reading the material.

The following questions are designed to see how well you still remember the material. Scores will be posted according to the number found on the upper right hand corner of this page, which will allow you to compare your score with those of your classmates.

Answer each question by selecting the best answer and darkening the corresponding section of your answer sheet. Example:

If the answer to number one is A, then darken the area between the two lines for A after 1. Make sure the entire area between the two lines is completely darkened and that you place no other marks on the answer sheet.

1. ▮ ‖ ‖ ‖ ‖
   A B C D E

Please make no marks on the list of questions.

RETENTION TEST

TEST ON LASER

1. A laser beam is focused with
   - A. magnets
   - B. prisms
   - C. lenses
   - D. mirrors

2. The chain reaction occurs between the __________ atoms in the ruby rod.
   - A. ruby
   - B. chromium
   - C. crystal
   - D. uranium

3. When a laser beam emerges from a laser device
   - A. it spreads rapidly
   - B. it is in the form of a concentrated beam
   - C. it radiates in all directions
   - D. none of these

4. If a laser beam struck each of the following types of materials, which would achieve the highest temperature?
   - A. opaque absorbative
   - B. opaque reflective
   - C. clear reflective
   - D. clear absorbative

5. In a laser device the capacitor
   - A. stores up electrons
   - B. needs charging
   - C. releases stored up electrons
   - D. all of these

6. The focusing of a laser beam
   - A. is not necessary
   - B. is very time consuming
   - C. is impossible
   - C. is done quickly and accurately

7. The joining of two pieces of metal to form a solid joint could best be accomplished by
   - A. machining
   - B. spectrum analysis
   - C. welding
   - D. shaping

8. Which of the following is an advantage of laser machining?
   A. very accurate
   B. material machined is removed from the work area
   C. can machine any material
   D. all of these

9. The energy of a laser beam is used in the form of _______________in metalworking applications.
   A. light
   B. rays
   C. heat
   D. sound

10. Which of the following was not discussed as a type of laser?
    A. gas
    B. liquid
    C. solid
    D. atomic

11. The energy of a laser beam is concentrated by using
    A. lenses
    B. prisms
    C. magnets
    D. mirrors

12. Laser light is re-directed
    A. with lenses
    B. naturally
    C. with prisms
    D. with mirrors

13. A capacitor
    A. discharges slowly
    B. discharges rapidly
    C. destroys excess electrical energy
    D. converts electrical energy to heat

14. The flash lamp on a laser device
    A. generates the laser beam
    B. produces photons which activate the ruby rod
    C. stores electrons
    D. stores photons

15. Which of the following must be performed in a vacuum
    A. laser welding
    B. electron welding
    C. laser machining
    D. conventional machining

16. The energy level of an atom can be raised by
    A. applying external energy
    B. removing external energy
    C. providing a neutral energy field
    D. placing atoms in a vacuum

17. The beam is released from a laser device by breaking through a
    A. lens
    B. prism
    C. mirror
    D. port hole

18. If a laser beam struck each of the following materials, which would achieve the lowest temperature?
    A. opaque reflective
    B. opaque absorbative
    C. clear reflective
    D. clear absorbative

19. In order for a meterial to be vaporized by a laser beam, it must be
    A. soft
    B. have a low melting point
    C. opaque
    D. reflective

20. A laser beam can weld metal surrounded by a
    A. gas
    B. air
    C. vacuum
    D. all of these

21. All energy released from the atoms during the chain reaction that is not released parallel to the ruby rod is
    A. redirected by lenses
    B. redirected by a magnetic field
    C. lost
    D. stored

22. Laser light having been emitted from a laser device becomes a beam
    A. with lenses
    B. naturally
    C. with prisms
    D. with mirrors

23. The energy in a solid-state laser is built up by a chain reaction of photons and
    A. ruby atoms
    B. chromium atoms
    C. crystal atoms
    D. uranium atoms

24. Most lasers are pulse type because of the need to
    A. adjust the beam
    B. charge the battery
    C. charge the capacitor
    D. adjust the voltage

25. Energy released from what part of the ruby rod in a laser device would be likely to be most powerful?
    A. end
    B. side
    C. both would be equal
    D. not possible to predict

26. Laser production tools
    A. have been used for many years
    B. are widely used
    C. will not be practical
    D. are not yet available

27. Oxidation and other undesirable chemical reactions do not occur when welding with a laser, because
    A. the welding is done in a vacuum
    B. of the rapidity of the heating action
    C. special gasses are used
    D. all of these

28. Which of the following materials can not be melted by a laser beam?
    A. diamonds
    B. stainless steel
    C. clear glass
    D. none of these

29. After welding with a laser, what consideration must be given to the oxide formed?
    A. the oxide must be removed
    B. the oxide need not be removed
    C. removal of the oxide depends upon the next process to be performed
    D. there is no oxide to speak of

30. The pulse-type beams of present day lasers are due to the characteristics of the
    A. capacitor
    B. resistor
    C. flash lamp
    D. magnetic field

31. An atom at rest is usually at its __________energy level.
    A. medium
    B. lowest
    C. highest
    D. can not predict

32. The type of material generally used in a solid-state laser device is_________________.
    A. synthetic ruby
    B. genuine ruby
    C. crystal
    D. stainless steel

33. Which of the following limits the application of electron welding?
    A. must be done in a vacuum
    B. limited as to the size of the piece being welded
    C. can not be used on all materials
    D. all of these

34. Under which of the following conditions can the laser function?
    A. in the atmosphere
    B. in a vacuum
    C. in space
    D. all of these

35. The laser machines metal by ______________the metal.
    A. cutting
    B. vaporizing
    C. melting
    D. shaping

36. In which of the following processes is the laser not used?
    A. melting
    B. bending
    C. vaporizing
    D. none of these

37. Solid-state lasers are most powerful because
    A. they are larger
    B. they have a larger number of active atoms
    C. they use transistors
    D. all of these

38. Lasers manipulate metal primarily by
    A. melting and vaporizing
    B. melting and shaping
    C. vaporizing and shaping
    D. melting, shaping and vaporizing

39. Spectrum analysis is used to
    A. shape metal
    B. analyze the composition of a material
    C. drill holes
    D. remove metal

40. Mirrors are used with laser light to_________the beam.
    A. concentrate
    B. spread
    C. focus
    D. direct

41. Which of the following characteristics must a metal have before it can be machined by a laser?
    A. brittleness
    B. hardness
    C. tensil strength
    D. none of these

42. Machining is the process of
    A. analyzing the composition of steel
    B. melting metal
    C. vaporizing metal
    D. performing operations on metalwork by machines

43. A laser beam
    A. penetrates the material it strikes
    B. heats by conduction from the outside in
    C. cuts by sawing motion
    D. separates atoms

44. Which of the following is the most often used type of laser?
    A. solid-state
    B. gas
    C. liquid
    D. semi-liquid

45. Which of the following limit the application of the laser?
    A. distortion of metal due to heat
    B. unwanted chemical reactions
    C. pulse type beams
    D. all of these

TRANSFER TEST

46. Which of the following photons of energy would have the best chance of emerging as part of the laser beam during the generation of the laser beam?
    A. one traveling away from the muzzle
    B. one entering the rod from the flash tube
    C. one released from a chromium atom
    D. cannot predict

47. A person walking into a powerful laser beam would
    A. not realize he had done so
    B. be burnt
    C. feel heat
    D. cannot predict

48. If you needed to make small holes in an electronic component during the next year, which of the following types of drills would you not order?
    A. a conventional drill
    B. laser drill
    C. electronic drill
    D. high frequency drill

49. Which of the following uses a different method of laser metal manipulation than the other two?
    A. welding
    B. machining
    C. spectrum analysis
    D. all the same

50. At the present time an intricate micro-welding operation would most likely be performed by
    A. gas welding
    B. arc welding
    C. electron welding
    D. laser welding

51. Drilling deeply into a material with present laser equipment would require
    A. one laser pulse
    B. a number of laser pulses
    C. pre-heated metal
    D. a vacuum

52. Which of the following could a laser weld?
    A. two pieces of opaque glass
    B. two pieces of metal in space
    C. two pieces of rock
    D. all of these

53. Lasers are used primarily for micro-operations because of their
    A. strength
    B. accuracy
    C. versatility
    D. size

54. If while welding you incorrectly turned the strength of the laser beam extremely high, what would be likely to happen to the material you were welding?
    A. it would melt
    B. it would vaporize
    C. it would split
    D. nothing

55. Which of the following meters positioned around the laser would show the greatest increase in energy as the laser began to generate and before it fired?
    A. a meter placed at the muzzle
    B. a meter placed along side
    C. a meter placed at the end away from the muzzle
    D. all the same

56. A bullet is shot at a can; the atoms of metal are at their highest energy level
    A. before the bullet strikes
    B. while the bullet is striking
    C. after the bullet strikes
    D. cannot predict

57. Which of the following meters positioned around a laser device would record the highest energy level during the generation of a laser beam before the beam is released?
    A. a meter placed at the muzzle end
    B. a meter placed along side
    C. both would be equal
    D. not possible to predict

58. Which of the following substances would not be melted by a laser beam?
    A. clear glass
    B. rock
    C. steel
    D. industrial diamond

59. You are wondering whether or not a piece of aluminum contains chromium, which of the following processes would you use to answer this question?
   A. welding
   B. spectrum analysis
   C. machining
   D. electron bombardment

60. In which of the following items would the atoms be at the highest level of internal energy?
   A. a ball while it is striking the ground
   B. a ruby rod
   C. a piece of glass
   D. a piece of coal

61. While welding with a laser, a thermometer is placed on the metal one foot from the welding area. Exactly the same type of joint with the same type of metal is also welded by conventional means and a thermometer is placed on the metal one foot from the welding area. Which thermometer will have the highest temperature reading?
   A. thermometer used with conventional welding
   B. thermometer used with laser welding
   C. both will read the same
   D. cannot predict

62. Laser rays as compared with the sun's rays are
   A. less dangerous
   B. equally as dangerous
   C. more dangerous
   D. neither are dangerous

63. You are faced with the problem of spreading the energy of a laser beam over a five square foot area, which of the following would you use?
   A. mirrors
   B. prisms
   C. lenses
   D. magnets

64. A laser beam travels as rapidly as
   A. sound
   B. a bullet
   C. a jet plane
   D. light

65. Which concentration of atoms would lend itself to the generation of the highest powered laser beam in a laser device?
    A. high
    B. medium
    C. low
    D. none of these

66. Atoms in a piece of rock would normally be at what energy level?
    A. high
    B. medium
    C. low
    D. cannot predict

67. Which of the following could not be used to weld two pieces of metal in space?
    A. laser welding
    B. electron welding
    C. conventional welding
    D. both B and C

68. In which of the following substances would a chain reaction be likely to produce the most energy?
    A. solid
    B. liquid
    C. gas
    D. semi-liquid

69. The metal actually being cut during laser machining is
    A. reused
    B. sold for scrap
    C. too small to bother with
    D. destroyed

70. Based on the discussion of laser beam generation, what device would probably be used to start a fluorescent lamp?
    A. spectroscope
    B. laser
    C. capacitor
    D. flash lamp

APPENDIX C-2

Communications Tests

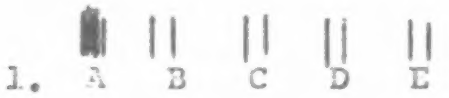
NAME______________________________________NUMBER__________

DIRECTIONS

About six weeks ago you read some information concerning lasers and answered six questions. Those questions were designed to see how well you could remember technical information immediately after reading the material.

The following questions are designed to see how well you still remember the material. Scores will be posted according to the number found on the upper right hand corner of this page, which will allow you to compare your score with those of your classmates.

Answer each question by selecting the best answer and darkening the corresponding section of your answer sheet. Example: If the answer to number one is A, then darken the area between the two lines for A after 1. Make sure the entire area between the two lines is completely darkened and that you place no other marks on the answer sheet.



Please make no marks on the list of questions.

RETENTION TEST

TEST ON THE LASER

1. If when selecting a conductor you viewed the end of one conductor and saw a single wire surrounded by a metal shield, what type of conductor would you have?
   A. regular telephone wire
   B. cable
   C. coaxial conductor
   D. none of these

2. Daylight represents
   A. a combination of light frequencies
   B. one pure light frequency
   C. light waves but not frequencies
   D. none of these

3. Transmission of voice signals over long distances requires amplifiers to
   A. strengthen the signal
   B. modulate the signal
   C. "filter out" unwanted signals
   D. all of these

4. The receiver portion of a telephone produces ________ so we can hear what has been said.
   A. light waves
   B. differences in air pressure
   C. electrical energy
   D. magnetic waves

5. Computer information is transmitted in the form of
   A. digital pulses
   B. Morse code
   C. light rays
   D. none of these

6. The modulator combines the carrier wave and the voice wave to produce two new waves equal to
   A. the difference between the two and the sum of the two
   B. the carrier wave frequency and the voice wave frequency
   C. the carrier wave frequency
   D. the voice wave frequency

7. Contrasted with a laser beam, ordinary light from a light bulb is
   A. not as pure in frequency
   B. not as intense
   C. not as directional
   D. all of these

8. Which of the following conductors is the most efficient means of transmitting many voice signals now in use?
   A. telephone wires
   B. cables
   C. coaxial conductors
   D. laser beams

9. Which of the following can not be used with the carrier technique?
   A. wires
   B. coaxial conductors
   C. regular light rays
   D. laser beams

10. A laser beam per square inch is
    A. less intense than the sun
    B. more intense than the sun
    C. as intense as the sun
    D. none of these

11. In order for a voice signal to be sent and received by the carrier technique
    A. one modulator and one de-modulator are needed
    B. two carrier wave generators of the same frequency are needed
    C. a transmitter and a receiver are needed
    D. all of these

12. During the transmission of a voice signal by conventional means the strength of the signal is reduced because part of the voice signal energy is turned into
    A. magnetic waves
    B. light rays
    C. heat
    D. interference

13. The energy in a laser device is generated by means of a
    A. magnetic accelerator
    B. electron beam
    C. chain reaction
    D. electric generator

3

14. A telephone cable contains
    A. many separate wires under one protective coating
    B. one wire surrounded by a metallic shell
    C. one wire surrounded by insulation
    D. none of these

15. The bandwidth to send one voice signal is
    A. 2,000 cps
    B. 3,000 cps
    C. 4,000 cps
    D. 5,000 cps

16. As the operating frequency of a communications system using conductors increases
    A. more voice signals can be sent
    B. the efficiency of the system decreases
    C. heat destruction of wires becomes an engineering problem
    D. all of these

17. The device used to separate the voice signal from the combined voice signal and carrier wave at a receiver is a/an
    A. antenna
    B. filter
    C. de-modulator
    D. resistor

18. Laser energy is usually generated within a/an
    A. synthetic ruby rod
    B. chromium rod
    C. natural ruby rod
    D. iron rod

19. In multiple voice transmission the carrier waves used to transmit separate voice signals
    A. may overlap in frequency
    B. must not overlap in frequency
    C. travel over the same pair of wires at different times
    D. travel over different wires

20. The major purpose of long distance telephone communication is
    A. distortion free electrical transmission
    B. to transmit and reproduce the original voice pattern
    C. a system of complex devices
    D. laser transmission

21. A coaxial conductor can transmit higher frequencies because
    A. it is a heavier wire
    B. it contains many wires
    C. it is less subject to heat damage
    D. it is surrounded by insulation

22. Which of the following frequencies would represent the highest tone?
    A. 150 cps
    B. 500 cps
    C. 1,000 cps
    D. 3,000 cps

23. Sounds are interpreted by the
    A. ear
    B. mind
    C. auditory nerve
    D. skin

24. Meaningful signals were first sent by using _________ light.
    A. focused
    B. polarized
    C. beamed
    D. reflected

25. In order to send a voice signal, TV signal or computer information over a wire from one place to another they must be converted into
    A. sound waves
    B. light rays
    C. electrical pulses
    D. interference

26. Which of the following is not suggested as a use of laser bandwidth?
    A. voice communication
    B. TV communication
    C. computer communication
    D. short wave communication

27. A telephone transmits____________________from one place to another over wires.
    A. sound waves
    B. light waves
    C. voice signals
    D. digital signals

28. If you wanted to send a very high frequency signal across the country at the present time, which of the following would you use?
    A. telephone wires
    B. cables
    C. coaxial conductors
    D. laser beams

29. A laser beam is
    A. combination of colors
    B. a combination of frequencies
    C. pure in color and frequency
    D. pure in frequency but not in color

30. Using the carrier technique, the receiver
    A. combines the carrier wave frequency with the incoming signal to produce the original frequency
    B. combines the original voice signal with the carrier wave frequency to produce the transmitted frequency from the transmitter
    C. receives only the original voice signal
    D. none of these

31. Sound travels through air in the form of
    A. light
    B. pulses
    C. waves
    D. beams

32. Sound waves are received by the
    A. ear
    B. mind
    C. auditory nerve
    D. skin

33. Of the two new waves produced by the modulator, the unused one is
    A. not produced
    B. filtered out
    C. stored
    D. used with another voice signal

34. A coaxial conductor contains
    A. many separate wires under one protective coating
    B. one wire surrounded by a metallic shell
    C. one wire surrounded by insulation
    D. none of these

35. What is the relationship between frequency of transmission and efficiency of transmission in conductors?
    A. as frequency goes up efficiency goes down
    B. as frequency goes down efficiency goes down
    C. as frequency goes up efficiency goes up
    D. there is no relationship

36. Using the carrier technique, a second conversation can be transmitted over a pair of wires by
    A. using a different carrier frequency
    B. using the wires after the first conversation is finished
    C. using different voice patterns
    D. none of these

37. Most ordinary light sources do not
    A. radiate in almost every direction
    B. produce relatively low energy light
    C. produce impure frequencies
    D. naturally produce a beam of light

38. Which of the following frequencies would represent the lowest tone?
    A. 150 cps
    B. 500 cps
    C. 1,000 cps
    D. 3,000 cps

39. Laser light is directed with
    A. lenses
    B. mirrors
    C. prisms
    D. magnets

40. Laser light represents
    A. combination of light frequencies
    B. one pure light frequency
    C. light waves but no frequencies
    D. many colors

41. Which of the following is not a limitation of laser communication?
    A. the need to protect the beams
    B. diffusion of laser beams due to mist or smog
    C. necessity for keeping the beams pointed in the proper direction
    D. the extreme power of the laser beams

42. A laser beam is hampered by
    A. cold weather
    B. a vacuum
    C. rain
    D. all of these

43. If you were planning to send many conversations with the carrier technique, which of the following would you not use?
    A. laser beam
    B. ordinary light beam
    C. coaxial conductor
    D. telephone wire

44. A perfected laser beam could be sent from San Francisco to New York
    A. unaided
    B. through pipes alone
    C. through pipes with mirrors
    D. can not be done

45. Which of the following characterizes a laser beam?
    A. high frequency
    B. large bandwidth
    C. constant frequency
    D. all of these

TRANSFER TEST

46. If you viewed the end of one conductor when selecting a conductor and saw about 24 separate wires, what type of conductor would you have?
    A. a regular telephone wire
    B. cable
    C. coaxial conductor
    D. none of these

47. If you listed the different colors of light contained in a laser beam and the different colors of light contained in an ordinary light beam, which list would be longer?
    A. laser list
    B. ordinary light list
    C. both would be equal
    D. not possible to predict

48. Which of the following pairs of modulated frequencies transmitting voice signals should not be sent together over the same pair of wires?
A. 50,000 - 60,000 cps
B. 50,000 - 58,000 cps
C. 50,000 - 55,000 cps
D. 50,000 - 53,000 cps

49. If you had a transmitter at home and it was receiving an unwanted signal from a motor which was occupying Bandwidth, you would remove it by
A. filtering
B. modulating
C. receiving
D. reflecting

50. A person walking into a powerful laser beam would
A. not realize he had done so
B. be severely burnt
C. feel heat
D. none of these

51. Which of the following would be most like the auditory nerve which connects the ear and the brain?
A. receiver
B. transmitter
C. telephone wire
D. modulator

52. The portion of a radio that first produces the voice signal which is later fed into a loud speaker is the
A. antenna
B. de-modulator
C. capacitor
D. resistor

53. When sending a high frequency signal over a wire circuit and the wire begins to get hot, what is wrong?
A. the signal needs to be amplified
B. the wire has too much insulation
C. the frequency is too high
D. none of these

54. You are going to call four friends. Bill lives one mile from your house, Tom five miles, John ten miles, and Fred twenty miles. If you had a direct wire from your house to each of your friends' houses, which boy would be most difficult to hear if they all spoke in the same manner?
A. Bill
B. Fred
C. John
D. Tom

55. If you and a friend were next to each other and speaking, you could not hear him
A. under water
B. in the air
C. in a vacuum
D. in a sound-proof room

56. A radio-phone
A. converts sounds directly to radio waves
B. converts sounds to electrical pulses and then to radio waves
C. converts light rays to electrical pulses
D. converts light rays to electrical pulses and then to radio waves

57. A telephone receiver is most like a
A. radio station
B. radio
C. toaster
D. light bulb

58. Which of the following signals would have to be strengthened most often in long distance communication?
A. 50,000 cps
B. 150,000 cps
C. 300,000 cps
D. 500,000 cps

59. If a 50,000 cps carrier wave were modulated with a 500 cps voice signal at the transmitter, a 50,500 cps signal would result. If this 50,500 cps signal is received by a receiver and modulated with a 49,000 cps carrier wave, what frequency will result?
A. 250 cps
B. 500 cps
C. 1,000 cps
D. 1,500 cps

60. Which of the following devices converts sound to electrical energy and back to sound again?
    A. telephone
    B. radio
    C. short-wave radio
    D. all of these

61. The guitar in an electric guitar system is most like what portion of a telephone system?
    A. transmitter
    B. modulator
    C. receiver
    D. filter

62. A telephone is going to be used to send the sound portion of a musical TV show which ranges from 15 cps to 15,000 cps. Which of the following bands would be capable of sending the signal without wasting bandwidth?
    A. 50,000 cps - 60,000 cps
    B. 60,000 cps - 72,000 cps
    C. 72,000 cps - 87,000 cps
    D. 87,000 cps - 107,000 cps

63. Which of the following could be sent by the carrier technique?
    A. sounds converted to electrical energy
    B. colors converted to electrical energy
    C. numbers converted to electrical energy
    D. all of these

64. The term "adequate bandwidth" refers to
    A. a bandwidth capable of sending the entire range of frequencies of a given type of signal
    B. a bandwidth capable of sending high and low tones
    C. a bandwidth equal to 4,000 cps
    D. a bandwidth equal to 4,000,000 cps

65. Laser rays as compared with the sun's rays are
    A. less dangerous
    B. equally as dangerous
    C. more dangerous
    D. neither are dangerous

66. The process of separating gas and fuel oil from crude oil so that they can be sold is most like the communications process of
    A. modulation
    B. de-modulation
    C. transmitting
    D. receiving

67. Which of the following is not an effective communications technique?
    A. convert sound waves to electrical energy and back to sound waves
    B. convert sound waves to different light frequencies and back to sound waves
    C. convert sound waves to electrical energy and back to interference
    D. all of these

68. A voice signal representing a conversation can be transmitted as
    A. electrical pulses over wire
    B. radio waves through the air
    C. micro-waves through the air
    D. all of these

69. You see four beams of light but can not see where the light is coming from, which is most likely to be the laser beam?
    A. a many color bright light
    B. a narrow many colored beam
    C. a one-colored beam
    D. a high frequency light beam of four colors

70. If you wanted to send one voice signal a distance of one mile without using the carrier technique, which of the following would be most efficient to use?
    A. telephone wires
    B. cables
    C. coaxial conductors
    D. laser beams

APPENDIX D

COMPOSITION OF THE PURPOSIVE SAMPLE OF EDUCATIONAL PSYCHOLOGISTS AND INDUSTRIAL EDUCATORS, AND THE PANEL

D-1 Composition of the Purposive Sample of Educational Psychologists and Industrial Educators

D-2 Panel

APPENDIX D-1

PURPOSIVE SAMPLE OF EDUCATIONAL PSYCHOLOGISTS AND INDUSTRIAL EDUCATORS FROM THE UNIVERSITY OF MINNESOTA

1. Educational Psychologists
    - a. Dr. Cyril J. Hoyt, Professor of Educational Psychology
    - b. Dr. Paul E. Johnson, Assistant Professor of Educational Psychology
2. Industrial Educators
    - a. Dr. Jerome Moss, Jr., Associate Professor of Industrial Education
    - b. Brandon B. Smith, Research Fellow in Industrial Education
    - c. Marshall S. Hahn, Research Fellow in Industrial Education

APPENDIX D-2

PANEL

1. Mr. Brandon B. Smith, Research Fellow in Industrial Education, University of Minnesota
2. Mr. Marshall S. Hahn, Research Fellow in Industrial Education, University of Minnesota
3. Mr. Rodney Van Sickle, Post-High School Instructor of Electronics, Minneapolis Area Vocational-Technical School
4. Mr. Robert K. Larson, Post-High School Instructor of Electronics, Minneapolis Area Vocational-Technical School